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ABSTRACT

This final report summarizes two years of research carried out by the Indigenous Mathematics Project at five community schools in Papua New Guinea. The first section gives a brief overview of the study, including a summary of the important results, overall conclusions, and recommendations. It is written using non-technical terms whenever possible, to provide a reasonable level of understanding of the outcomes. The final two sections describe, in some technical detail, the research methodology and design; the data analysis procedures; and the results of the analysis of achievement, cognitive, and classroom observation data. Recommendations are made regarding the revision of the current Mathematics for Community School syllabus and subsequent textbook production. The study concludes that the prompt introduction of an appropriate, locally developed textbook for grades 4, 5, and 6, and comprehensive teacher handbooks for grades 1, 2, and 3, would, in conjunction with minimal learning aids and adequate in-service training, have significant effects on teacher competence and student achievement. The results were considered especially encouraging relative to potential gains in rural and remote-rural settings. Appendices outline a proposed schedule for curriculum development and objectives for community school mathematics programs. (MNS)

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INDIGENOUS MATHEMATICS PROJECT

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TEACHING AND LEARNING MATHEMATICS IN THE COMMUNITY SCHOOLS OF PAPUA NEW GUINEA

Randall Souviney

Working Paper 20
August 1981

THE INDIGENOUS MATHEMATICS PROJECT

This series of working papers and research reports has been published to provide a comprehensive source of documentation on research and development efforts associated with the Indigenous Mathematics Project. The Project was established in 1977 by the Government of Papua New Guinea to investigate various aspects of traditional mathematics development. During the first phase (1977–79) of the five year program, basic research in crosscultural cognitive development was carried out and indigenous counting, classification and measurement systems used throughout the country were documented. During the second phase of the project (jointly funded by the Department of Education and UNESCO), pilot instructional materials were developed and trialled. The intent was to assess the feasibility of utilizing complementary aspects of indigenous and Western mathematics as a basis for developing culturally relevant student materials, instructional aids and teachers' guides which reflect the practical constraints of the community school environment. The results of IMP work are intended to inform future curriculum development in an effort to provide more appropriate instructional materials and learning aids for Community Schools throughout Papua New Guinea.

Series Editor: Randall Souviney
Managing Editor: Jacquie Wathen

TEACHING AND LEARNING MATHEMATICS IN THE COMMUNITY SCHOOLS OF PAPUA NEW GUINEA

Randall Souviney
University of California, San Diego
August 1981

This final report summarizes research carried out at five community schools in Papua New Guinea. It culminates the efforts of several researchers involved in various aspects of the study over a two year period. The analysis of achievement, cognitive and classroom observation data are discussed. Recommendations are made regarding the revision of the current Mathematics for Community School syllabus and subsequent textbook production. The study concludes that the prompt introduction of an appropriate, locally-developed textbook for grades four, five and six, and comprehensive teacher handbooks for grades one, two and three, would, in conjunction with minimal learning aids and adequate inservice training, have significant effects on teacher competence and student achievement. The results were especially encouraging relative to potential gains in rural and remote-rural settings.

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Though many individuals contributed to the development of the current report, any errors or omissions remain the sole responsibility of the author.

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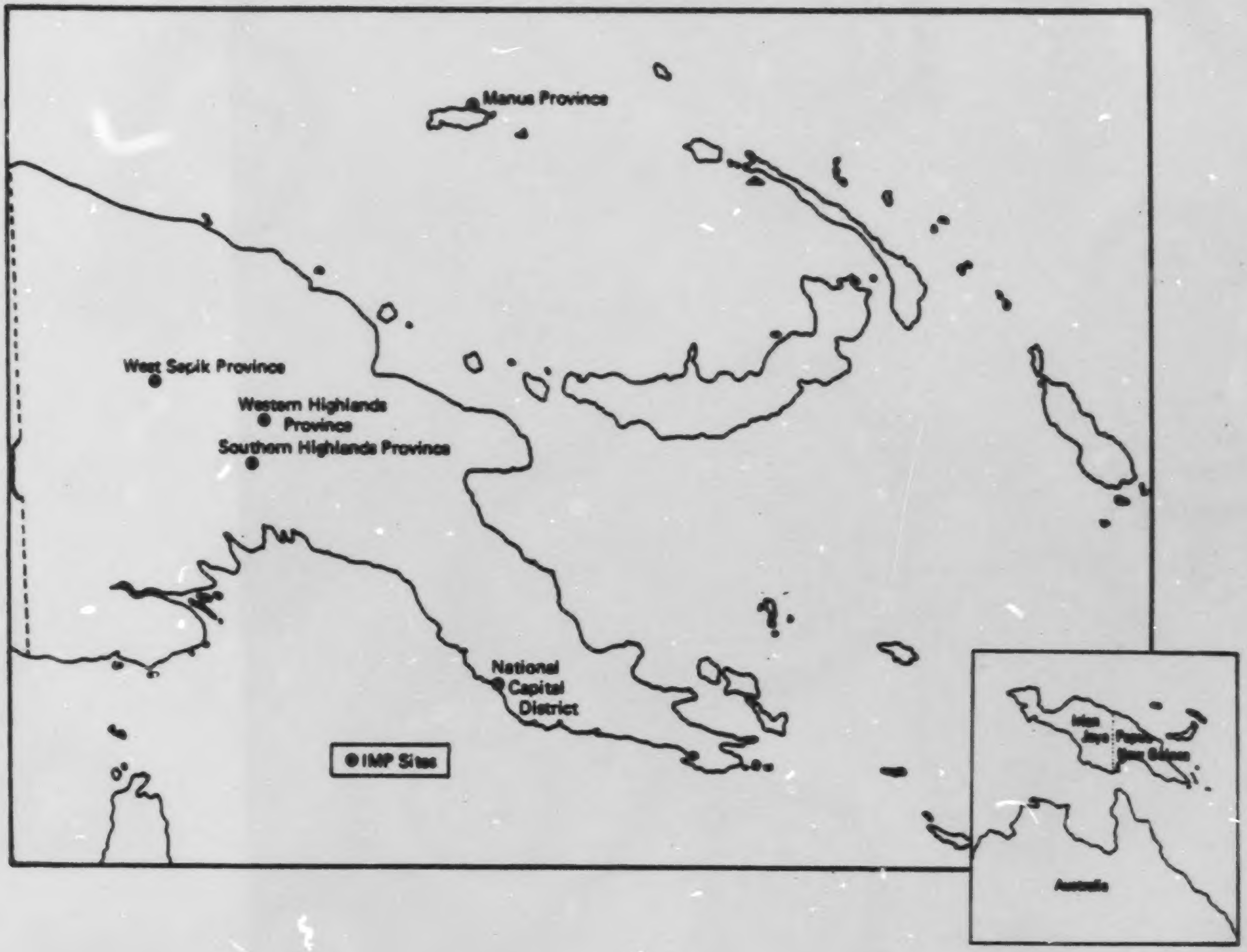
PAPUA NEW GUINEA


Manus Province
West Sepik Province
Western Highlands Province
Southern Highlands Province
National Capital District
● IMP Sites
Irian Jaya
Papua New Guinea
Australia

NOTE TO THE READER

For your convenience this report is divided into three sections. The first section gives a brief overview of the study including a summary of the important results, overall conclusions and recommendations. This initial section is written using non-technical terms wherever possible and should offer a reasonable level of understanding relative to the outcomes of the study.

The final two sections describe, in some detail, the research methodology and design, the data analysis procedures and a detailed description of the results. Additional summary data is presented in the final section which may be of interest to others conducting research in this area. These sections are included for the reader who is interested in the more technical aspects of the study.

Em i bikpela bokis. Em i gat tit. Na taim yu paitim em, em i krai.
(piano in *Melanesian Pidgin*)

SECTION I

SUMMARY AND RECOMMENDATIONS

TEACHING AND LEARNING MATHEMATICS IN THE COMMUNITY SCHOOLS OF PAPUA NEW GUINEA

In their study of mathematics learning among the Kpelle, Gay and Cole (1967) offer the optimistic conclusion that the history of poor school performance experienced by these children was attributable not to some elusive intellectual deficiency inherent within the culture, but rather to inappropriate curriculum materials and instructional philosophy and methodology associated with schooling itself. This seems, on the whole, to be a healthy attitude to be adopted by those charged with committing education on the general population.

In developing a democratic society it is incumbent upon the education community to view their students as clients; to accept, to celebrate their view of reality. If mathematical literacy is to address dual purposes of technological and village-level development, it is unsatisfactory to simply institute a selection procedure to sort-out children with high "education potential" while continuing a business-as-usual approach to teaching, at least at the community school level.

Gay and Cole suggested that the primary characteristic which prevented Kpelle children from succeeding in school was their unquestioning reverence towards knowledge possessed by adults. While such behaviour may be necessary for survival in the traditional village environment, in school such behaviour is clearly inefficient. Without access to the scientific tool of initially reserving judgement while engaging in a process of objective analysis, the masses of new information encountered in school are destined to remain a mystery of unconnected facts. The task of the teacher, then, is to help the child translate Western mathematical ideas using analogs in their own experience and extend these ideas wherever necessary to define concepts that are not readily expressable in local terms. The final objective remains, however, to instill sufficient understanding of mathematics to enable people to successfully confront Western technology and defend themselves from its effects if necessary.

In order to effect the quality of mathematics education in any significant way, these general pedagogical principals must be embodied in specific curriculum materials accompanied by practical teaching procedures. First, how do educators identify those concepts that are relatively easy to model using experiences common to the culture of the students?

Saxe (1981) investigated the use of the Aksapmin body-counting system by children learning school mathematics and men operating trade stores. The capabilities of the traditional numeration system are currently being stretched and adapted to meet the press of new demands. An example involved inventing a clever procedure to "store" the minuend (top number) of a subtraction problem by touching the appropriate body part with the forefinger of the opposite hand. They then counted the body part names of the numbers up to the subtrahend (bottom number) while retracing the sequence, effectively instituting a consistent "stop rule". For example, if "shoulder" means ten, to subtract 2 the child points to "shoulder" (ten), moves his finger to "upper arm" (nine) and says "thumb" (one), then moves to "elbow" (eight) and says "forefinger" (two). He has effectively counted up to the subtrahend (forefinger – two) while counting down from the minuend (shoulder – ten). When he reaches the body part representing the subtrahend (forefinger – two) he institutes the "stop rule" and looks at current body position (elbow). The answer is "elbow" (eight).

Such invented procedures rooted in the child's experience, when understood by the teacher, provide a useful starting point for the development of symbolic algorithms. Ginsburg, Russel and Posner (1981) offer further examples in their study of the development of arithmetic skills in African and American children. Analyzing protocols of children solving simple addition problems they concluded that children from the Ivory Coast experienced the same pattern difficulties as their American peers. In both groups invented procedures played a significant role in successfully completing computations.

The task of the teacher then becomes one of helping children invent consistent ways of operating on already existing ideas that lead to key mathematical concepts. For example, from simple counting, children must develop the notion of exchange and place-value before operations with large numbers take on meaning. Measurement using egocentric attributes (eg. tall, thin, fast) must lead to relative labels (eg. taller, thinner, faster), unit measure (eg. 2 metres, 25 kilograms) and eventually comparisons between unit measures (eg. three centimetres longer). Often physical materials and pictures play a fundamental role in facilitating communication between the ideas in the teacher's head and those possessed by students. The curriculum and accompanying teaching practices play a central role in this complex enterprise.

Mathematics for Community Schools

A modern system of education has been in existence in Papua New Guinea for only about 20 years. Attempts at developing a modern mathematics curriculum for use in primary schools was initiated in 1964 under the tutorship of Zoltan Dienes. Over the next ten years various teams of mathematics educators developed several adaptations of the Dienes inspired syllabus, beginning with a kit-based Temlab program and culminating with the current *Mathematics for Community Schools* syllabus and teachers guides.

During this period of curriculum revision, the Territories of Papua and New Guinea became a unified independent nation. This event had profound effects on the whole education enterprise. The new government soon adopted the long range goal of instituting universal primary education by 1990 and the short term objective of completing the localization of the primary teaching force. In 1970 the staff and inspectorate of the approximately 1500 community schools contained a sizeable minority of relatively well trained expatriates. By 1979 a completely localized staff of over 9000 teachers were servicing approximately 280,000 students at 2000 schools. In effect a curriculum designed for a relatively well trained, supervised and equipped staff is now implemented by teachers with a maximum of ten years academic schooling and two additional years of teacher training, many in extremely remote schools.

Attempts were made to adapt the final version of the MACS program to local conditions. For example locally available bush materials were incorporated into the lessons as much as possible. However, key lessons still depend on the availability of multibase blocks, attribute materials and sizeable quantities of paper products, none of which are readily available to the rural teacher. Many community school teachers observed as part of this study have expended commendable efforts to compensate for such obstacles.

Many teachers referred to a conscientious attempt on the part of their college instructions to prepare them for the "reality" of life in the bush schools. It is clear that these compensatory efforts on the part of motivated teachers are by no means universal or long lasting. A high degree of teacher "burn out" is reported, caused not only by the lack of teaching materials but also the constant frustrations associated with concerns relative to housing, health, salary and isolation.

As a consequence many MACS lessons are ineffectually presented or skipped altogether. There is a temptation on the part of the teacher to forego the preliminary manipulative experiences, so important for effective concept development, relying instead on symbolic "chalk-talks" followed by oral drills or sets of exercises. At the other extreme, teachers often drill children on, say, base-5 operations, refusing to allow the class to move on until they have "mastered" this "modern-mathematics" objective.

Considerable misunderstanding surrounds the use of Dienes' "multiple-representation" model for learning as it applies to multibase arithmetic. Teachers tend to view operations with each base as a terminal objective, drilling children until they master the symbolic process at each level. The original intent of the multibase model was to provide **experience** using various bases to develop the concepts of regrouping and place-value and **introduce** the algorithms for the four basic operations. This experience should lead to drill-and-practice with **base-10** arithmetic and eventual mastery. Such misuse of the fundamental methodology associated with the MACS course (ie. stressing mastery at each intermediate base), along with a serious lack of support materials, raises the question as to whether its inclusion in the current syllabus is, in fact, appropriate for the community schools in Papua New Guinea.

The current study attempted to look at this question (among others) by developing a modest collection of instructional materials designed to enhance and simplify the teaching of number operations in the MACS course. Subsequently a carefully observed trialling was carried out at five school sites representative of various cultures throughout Papua New Guinea.

The current effort follows an extensive body of research carried out under the auspices of the Indigenous Mathematics Project over the past five years. The IMP, begun in 1976, grew out of concerns for apparent unequal distribution across various population subgroups of jobs in the wage-employment sector and positions in tertiary institutions (Lancy, 1980). In recent years this issue has been, to some extent, subsumed by an increasing concern with the overall standard of education at all levels. The current debate is as much concerned with the definition of "standards" in the Papua New Guinea context as it is with assessing its imminent demise.

On the one hand it is argued that levels of mean achievement are dropping at all levels of education. Ross (1980) concluded that the alledged erosion of standards is due primarily to increased student intake and transition rates. This result is not surprising if one considers that increasing school intake from a static population virtually guarantees a student pool with a wider range of abilities. Without an accompanying increase in the **quality** of instruction, mean achievement scores will be depressed.

A counter proposal perhaps, is to gauge the standard of education in Papua New Guinea by more general measures of achievement such as the literacy rate in English, Pidgin and/or the vernacular. Advancement towards universal literacy (both language and mathematics) might reflect a more realistic view of educational development than form-four test results. Three projects currently underway in Papua New Guinea are engaged in village level education programs, the effects of which may go largely unnoticed by those involved in formal education. The Tok-Ples Schools Project in the North Solomans Province (Kemelfield, 1981), the Adult Literacy Campaign in the Southern Highlands

Province (Croft, 1980), and the Adult Numeracy Project sponsored by the Commerce Department (Edwards, 1981) represent low-cost, grass-roots efforts to address the educational **standards** issue in the **village context.** If the projects survive the inevitable departure of their prime-movers, each could have a significant long range effect on the general standard of education-for-community-life. What with fulfilling manpower needs being a primary goal of formal education, this argument becomes particularly salient when one considers that by 1990 the number of National High School and tertiary graduates is expected to exceed the number of jobs available.

The implications for the community school system therefore are twofold. First the curriculum must enhance the ability of children from areas with disproportionally few high school entrants, to compete successfully for scarce secondary positions. Also as the country moves closer to its goal of Universal Primary Education (UPE), more and more children will return to the village after completing community school. Increased attention must be paid to the needs of this group of children who presently constitute 70% of the community school graduates. It is likely this percent will increase significantly over the next decade unless, of course, resources committed to UPE are unwisely diverted to secondary school development.

It is with a view towards these concerns that the Indigenous Mathematics Project turned its attention from documenting variations in cross-cultural cognitive development (Lancy, 1980; Lancy, Souviney and Kada, 1981) to analysing the effects of curriculum innovation on teacher behaviour and student achievement. Mehan (1978) and Bauersfeld (1979) point out the difficulties associated with interpreting classroom events in such a way that practical generalizations can be made which are transferable to other situations. They caution educational researchers not to rely solely on static measures of classroom events (test scores, minutes of instruction, classroom organization, etc.) in an attempt to understand the learning phenomenon. They suggest instead that if we are to have any hope of unravelling the complexities of the instructional process we must concentrate our attention on the **interaction** between these static elements. By carefully observing the playing-out of events as they occur and seeking to reconstruct these events with the advice of the participants themselves, we are better able to understand what actually took place and how to interpret the relationships between teacher behaviour, curriculum materials and student performance. This process of reflection and active negotiation of reality is useful in determining what people **actually** do as opposed to what they **think** or **say** they do.

In our work, classes at five sites were systematically observed in operation. We interviewed the teachers before and after each lesson to help us reconstruct the instructional events. Though the task proved to be exhausting for both the teachers and observers, we feel the continual negotiation of events that took place enabled us to develop a far more complete understanding of the complex mathematics classroom environment. A more detailed description of the research method and results are offered in sections two and three.

Summary and Discussion

The primary purpose of the current study was to assess the effect on achievement of supplying selected teachers with adequate instructional materials, aids and a detailed teachers' guide supported by two weeks of inservice training. In general, these conditions have not been adequately met throughout the implementation of the current MACS program. Developing additional student materials (activity sheets and manipulative aids) also afforded us the opportunity to alter elements within the current curriculum which, for practical or theoretical reasons, seemed out of place. For example we reduced the stress on multibase arithmetic since appropriate manipulatives have never been supplied to the schools as originally intended.

In order to maximize potential feedback relative to specific content and design factors, we decided to carefully observe the trialling exercise at a limited number of sites as opposed to relying on responses to surveys from a large number of schools. We went to considerable effort to place a well trained classroom observer at each site to document implementation activities, interview the teachers and students and develop a brief community school ethnography. Extensive cognitive development and achievement data was collected as well.

Five community schools participated in the study representing remote, rural and urban schools, highland and coastal cultures:

1. Manus Province (Remote-rural)
2. West Sepik Province (Remote-rural)
3. Southern Highlands Province (Rural)
4. Western Highlands Province (Rural)
5. National Capital District (Urban)

Two teachers from each site were selected to participate in an IMP sponsored inservice course. The two-week workshop was hosted by the Port Moresby Teacher In-Service College during school vacation and National Inservice Training Week, April 1980. One teacher from each school was subsequently selected to implement the pilot materials in grades two, four and six, beginning 14 July 1980.

A trained observer was assigned to each site to collect cognitive development and achievement data, monitor the teachers' implementation efforts and document a range of classroom events. Detailed field-note guidelines were developed and field-tested to enhance the comparability of the data collected (Levin, Gearhart and Souviney, 1980). Teachers and students were interviewed regularly, daily field-notes were compiled and selected lessons were audio-taped for later analysis. A more detailed description of the field-note procedures can be found in the Method section of this report.

Approximately 40 lessons were developed for each of grades two, four and six. These lessons were adapted from Term-3 activities suggested in the current MACS teachers' guides. Additional developmentally structured base-10 number-operation activities were included (Souviney, Keyser and Sarver, 1978). Measurement and classification activities were also provided, however, due to time constraints, no geometry activities were included and logical relations was de-emphasized.

Student activity booklets were developed and supplied on a one-to-one basis. Each non-consumable activity-sheet provided pictures and instructions to help students work through the lessons. A minimal set of inexpensive learning aids was developed to support instruction.

Each site was supplied with the following materials:

1. Student Activity Booklets (one per student — grades two, four and six)
2. Teacher's Notes (two sets per school).
3. Learning Aids:

a) Base-10 Materials (die-cut cardboard ones, tens and hundreds – 50 sets per school)
b) Coins (die-cut cards – 40 sets per school)
c) Kina Cards (die-cut attribute cards – 40 sets per school)
d) Wooden Cubes (5 cm x 5 cm dice – 20 per school)
e) Pan Balance with mass-pieces (5 sets per school)
f) Metre Stick (8 per school)
g) Trundle Wheel (4 per school)
h) Squared Paper (1 cm^2 – 30 sheets per student)

Achievement Results: Several measures of achievement and cognitive competence were administered. Though statistically significant differences were found between schools, the patterns of differences were not consistent. Highlands schools in general showed lower achievement levels than the coastal sites in mathematics achievement. Though English competence was highly correlated with mathematics achievement, the site with the highest reading achievement scored second or perhaps third in overall maths achievement. The West Sepik subjects, who scored the lowest on most measures, performed admirably on the oral dictation exercise. Table 1 shows the pooled grade four and six mean achievement results for the five sites.

Table 1

POOLED GRADE FOUR AND SIX MEAN ACHIEVEMENT BY SCHOOL (%)

Site	PMAT2	PMAT3	PMAT4	READ	DICT	n_{pmat2}
MP	60.7	65.1	64.6	85.3	88.0	52
WSP	51.9	59.0	61.0	75.3	89.7	52
SHP	65.7	68.7	70.7	83.5	88.3	65
WHP	53.3	56.7	59.1	74.1	74.6	67
NCD	59.8	61.7	63.5	86.0	86.6	64
$\bar{X}$	58.3	62.4	63.8	80.8	85.4	60

MP = Manus Province
WSP = West Sepik Province
SHP = Southern Highlands Province
WHP = Western Highlands Province
NCD = National Capital District

PMAT2 = pre-test
PMAT3 = post-test
PMAT4 = retention-test
READ = sentence completion test
DICT = oral dictation test

The two most rural sites (West Sepik and Manus) exhibited little similarity in their achievement profiles, suggesting that proximity to provincial education services may have only a contributing influence on student achievement.

Gains in mathematics achievement were significant for all three grades over the six week trialling period. The average gain was 4.6% during the implementation period (DELTA32 = PMAT3 – PMAT2) and 1.6% during the retention period (DELTA43 = PMAT4 – PMAT3). Significantly more growth took place during the observation period ($t = 5.1$, $p < .001$). Table 2 gives a summary of achievement gains across the trialling and retention periods.

Table 2

DELTA32 AND DELTA43 BY GRADE (%)

Grade	DELTA32	DELTA43
2	7.8	0.9
4	3.1	1.0
6	3.7	2.5
$\bar{X}$	4.6	1.6

Observation period: DELTA32 = PMAT3 – PMAT2
Retention period: DELTA43 = PMAT4 – PMAT3

The variance associated with PMAT2, PMAT3 and PMAT4 offers additional encouragement with regard to the success of the implementation. The standard deviation decreased from 17.2 for PMAT2 (pre-test) to 16.0 for PMAT3 (post-test). Since the mean increased from PMAT3 and the top scores did not change significantly, we are left with the conclusion that the subjects on the lower end contributed more to the mean gain than those at the top.

Table 3

MEAN ACHIEVEMENT BY GRADE

Grade	PMAT2	PMAT3	PMAT4	READ	DICT	n_{pmat2}
2	30.1	36.9	38.4	47.3	24.9	114
4	52.6	55.7	56.8	74.9	81.1	157
6	64.3	68.8	71.1	86.3	89.3	143
$\bar{X}$	50.4	54.6	56.9	75.3	72.8	138
SD	17.2	16.0	16.5	19.5	27.9	

SD = standard deviation

We conclude that the curriculum contributed more to the growth of the average and below average children.

It can be argued that subjects receiving the lowest scores on the pre-test could be expected to show greater gains since they are confronted with relatively simple previously-missed items while the students at the top are confronted with more difficult missed exercises. The fact that grade two subjects gained on the average about twice as many percentage points from PMAT2 to PMAT3 as those in grade four and six, could be interpreted to support this contention. However, even though the mean continued to increase from PMAT3 (post-test) to PMAT4 (retention-test) the standard deviation increased to SD = 16.5, implying a broadening of achievement spread during the retention period.

We conclude that the highly perceptual learning aids (base-10 materials, coins, squared paper, kina cards), the student activity books and small-group class organization, contributed to the reduced variance in student achievement during the trial period. The difference between the top and bottom school based on pooled grade four and six achievement scores also decreased more between PMAT2 and PMAT3 (13.8% to 12.0%) than between PMAT3 and PMAT4 (12.0% to 11.6%).

Though it appears that IMP's involvement at the five sites positively effected overall mathematics achievement the question remains as to whether to attribute this growth to the curriculum, the preliminary inservice course, or simply the motivation associated with the presence of the full-time observer. We suspect the combined effect of these factors contributed significantly to the surge in the achievement.

A significant difference was found between sites based on pooled grade four and six PMAT2 results ($F = 1.73$, $p < .001$). The five sites divided into two homogenous subgroups with the SHP, MP and NCD sites achieving significantly higher than the WHP and WSP sites. Similar results were found for READING ($F = 11.2$, $p < .001$). Significant differences were also found between sites with regard to DICTATION scores as well ($F = 26.5$, $p < .001$) though surprisingly the WSP site ranked above all the other sites. Perhaps the extensive use of NBC radio broadcasts throughout the year at this extremely remote site had its effect on the results of this measure.

It is interesting to note that due to prior cognitive development research we expected the NCD and MP sites to attain higher achievement scores than the highland sites. The SHP school, however, consistently outperformed all other sites in mathematics achievement.

As expected reading achievement was higher in the coastal regions than the highlands sites. Though there is a reasonably high correlation between PMAT 2, READING and DICTATION scores ($r = 0.76$ and $r = 0.80$ respectively) the relationships are by no means linear. SHP achieved higher means in maths (significantly in grade six) than NCD, while the situation is reversed for READING and DICTATION results. English language competence seems to have a strong positive effect on mathematics achievement up to an unspecified threshold, beyond which some other factor (possibly reasoning or problem solving ability) comes into play.

Improving language skills in the lower grades may therefore elicit a greater effect on mathematics achievement than in the upper grades where threshold language skills necessary to support mathematics learning have been attained to a greater extent. This contention certainly deserves further attention and could provide a basis for practical solutions to persistent instructional problems. More stress on the explicit development of mathematical vocabulary and appropriate grammar would seem central to any effective primary syllabus.

Reed and Wainman (1977) and Read (1981) offer convincing evidence that any relationship between language competence and mathematics achievement found in young children seems to disappear at the tertiary level. In fact measures of student language and mathematics achievement administered in Swaziland and Papua New Guinea showed consistent, small but significant, negative correlations. A native English speaker may take for granted expressions that are confusing to the second language speaker. For example the members of a recent workshop in Goroka, Papua New Guinea, compiled the following list of English expressions which designate subtraction:

1. Six subtract three.
2. Subtract three from six.
3. Take three from six.

4. Six minus three.
5. Six take away three.
6. Six less three.
7. What is three less than six.
8. Decrease six by three.

Though all eight expressions suggest the subtraction problem 6 – 3, the syntax can be very confusing to second language speakers (and many native English speakers as well).

Attention must be given to the obvious problems children encounter as they endeavour to understand the highly technical, relational language required in mathematics. It must also be remembered that for many students English is their third, fourth or in some cases fifth language. In his study of language use and mathematics learning, Jones (1981) concluded that community school children in Papua New Guinea gained little in their mathematical language ability between grade two and grade five. This period is contrasted with the rapid language development of native English speakers during this period. Those children going to provincial high school eventually attain comparable levels of mathematical language to their counterparts, though such development is far too late to help those children learning mathematics in the community schools. He concluded that "arithmetic has every chance of becoming a meaningless set of rules associated with an equally meaningless set of words and hence little learning of value (is likely) to take place".

No viable alternative to English as the language of instruction seems to be available. It has been reported that as many as 80% of the student population in Papua New Guinea could be serviced with as few as eight of the over 700 languages represented (including Pidgin and English). The decision to encourage a wider range of acceptable languages of instruction has political as well as pedagogical ramifications. Decisions on language usage continues to be a political issue though educators have long argued their case for rationalizing the use of languages in the learning process.

A viable compromise might involve assigning, wherever possible, teachers to grade one and perhaps two who speak the local vernacular. Specific inservice training would be required in methods of using **tok ples** as a basis for developing technical terms and grammar in English.

Such an effort would by necessity be transitional in nature in that by the end of grade two all instruction would be in English. Language development would also be enhanced by the conscious effort to relate English concepts to their **tok ples** analogs. At worst such a decision would simply sanction a procedure already in common practice. We encountered frequent attempts on the part of teachers who didn't understand **tok ples** to explain a difficult concept by switching to Pidgin. It seems that when teachers become frustrated with children who don't understand an idea in English they switch to **any** language even though in this case the class did not understand Pidgin any better than English!

Certainly a persuasive argument could be made to encourage the posting of teachers to schools where they speak the local vernacular in order to work with children in their first year(s) of schooling. In lieu of a qualified vernacular speaking teacher, a local grade eight school-leaver could be recruited as a teacher's aid, especially in extremely rural sites. Both the children and the school leavers would benefit greatly from such an arrangement.

Item Analysis: Mean achievement results are only useful for comparing sites, grade levels and overall changes in achievement. In order to evaluate understanding of specific mathematics content it is necessary to look at individual test items and their relationship to subject-matter topics. PMAT items can be grouped under four content strands:

1. Measurement (11 items)
2. Number and Operations (36 items)
3. Mathematical Language (7 items)
4. Problem Solving Applications (8 items)

Computing achievement growth in each of the four content categories offers a clearer picture of the learning profile. Table 4 gives the mean percent of correct responses for PMAT2 and PMAT3 by content strand.

Table 4

ITEM ANALYSIS BY CONTENT STRAND
PMAT2 AND PMAT3

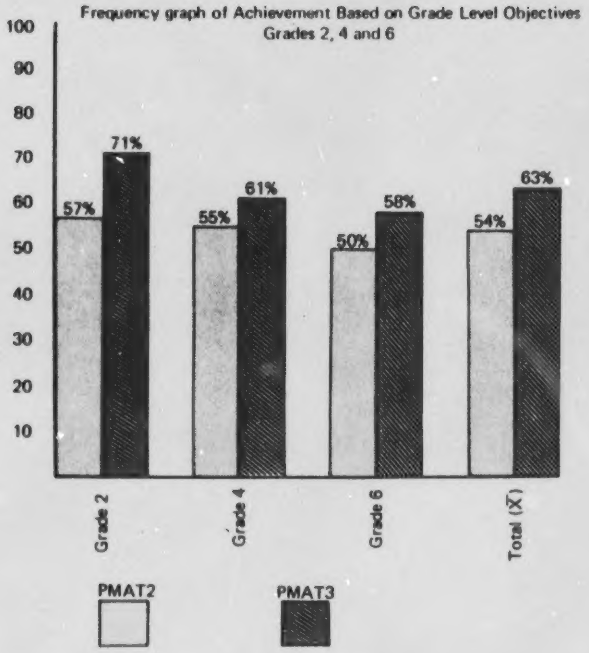
Content Strand	Grade							
	2		4		6		$\bar{X}$ pool	
	PMAT2 (%)	PMAT3 (%)	PMAT2 (%)	PMAT3 (%)	PMAT2 (%)	PMAT3 (%)	PMAT2 (%)	PMAT3 (%)
Measurement	49	58	70	78	83	85	71	74
Number and Operations	32	41	60	65	73	81	56	63
Mathematical Language	46	53	70	75	78	83	66	71
Problem Solving Applications	0.1	0.1	6	4	18	18	9	8
$\bar{X}_T$	30	37	53	56	64	69	50	55

$\bar{X}_{pool}$ = mean grades 2, 4 and 6.
$\bar{X}_T$ = mean across all strands.

The results clearly show that this group of students are far more competent at items involving measurement, number operations and mathematical language than those involving problem solving applications. Also, significant achievement gains are attained at all grade levels for all strands **except** problem solving. These results follow a similar pattern to the one reported by Carpenter, et al (1980) in their review of the Second National Assessment of Educational Progress conducted in the United States. They concluded that the students tested performed adequately on skill exercises, but were unable to demonstrate even the most basic problem solving abilities.

Further clarification is provided by Figure 1 which shows the mean percent of correct response on test items designated as **grade level** objectives. Of the 62 PMAT exercises, 33 addressed grade-two objectives, 31 for grade-four and 37 for grade-six. (Some objectives overlapped grade levels due to the reintroduction of selected concepts at later grade levels.)

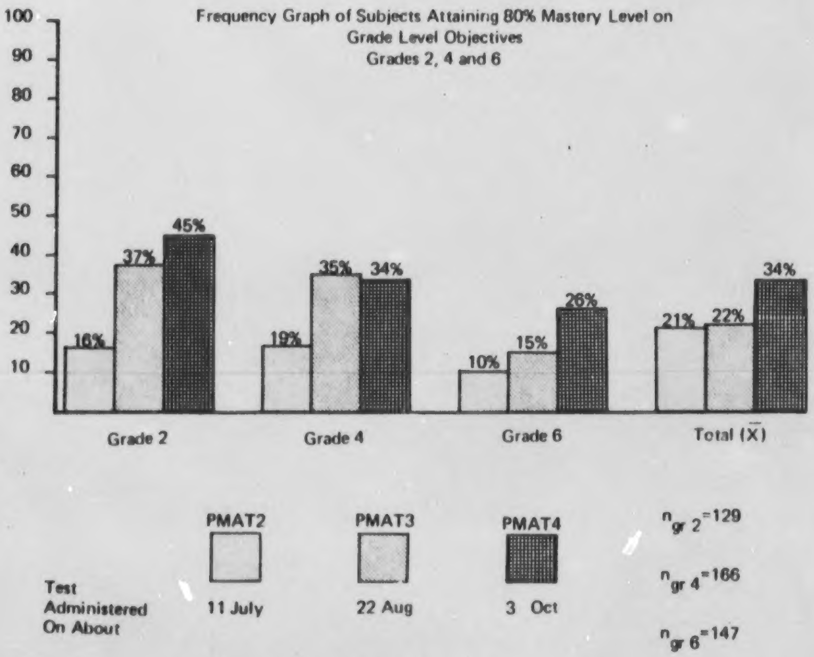
Figure 1


Frequency graph of Achievement Based on Grade Level Objectives
Grades 2, 4 and 6

Again, significant increases in achievement are noted across the six week trialling period but a different trend becomes apparent. Grade two children achieved a mean of approximately 71% on appropriate grade level objectives on PMAT3. Grade four achieved a mean of about 61% and grade six 58%. We conclude that as the content increases in difficulty in upper grades overall achievement on grade level objectives decreases.

Finally Figure 2 shows the percent of children attaining an arbitrary mastery level of 80% on grade level objectives. Results are presented for PMAT2, PMAT3 and PMAT4.

Figure 2


Frequency Graph of Subjects Attaining 80% Mastery Level on
Grade Level Objectives
Grades 2, 4 and 6

The percent of students attaining grade level expectations decreases from grade two to grade six (PMAT4: 45% – grade two; 34% – grade four; 26% – grade six). The percent attaining mastery consistently increases however over the three testing periods (11 July, 22 August, 3 October). These results are relatively encouraging when compared to results from previous achievement studies (Roberts and Kada, 1979; Edwards and Bajpai, 1979) that reported as low as 4% mastery level attainment for grade six students.

Further insight is offered by analysis of limited mathematics language achievement data collected from an International Primary School in Port Moresby and an elementary school in California, United States of America. Though firm conclusions should not be drawn from such a limited sample, the results in Tables 5 and 6 below offer a useful perspective for interpreting the Papua New Guinea achievement data. In order to make meaningful comparisons the data has been organized according to "years of schooling" as opposed to grade levels. Almost all International Primary and United States elementary school children attend a year of preparatory or kindergarten prior to grade one. This is not the case with Community School children. For example, four years of schooling corresponds to grade three for the International Primary and United States elementary schools and grade four for Papua New Guinea Community Schools.

Table 5

ACHIEVEMENT SCORES FOR COMMUNITY AND INTERNATIONAL PRIMARY SCHOOLS
PMAT4 AND READING (%)

Years of Schooling	PMAT4[3]		READING[3]	
	INT[1]	PNG[2]	INT	PNG
4	61.3	56.8	94.4	74.9
6	77.7	71.1	98.5	86.4
$\bar{X}$	69.5	64.0	96.5	80.7

1. International Primary School – grades 3 and 5 plus one year preparatory.
2. Community School sites – grades 4 and 6.
3. PMAT4 and READING administered eight months after the start of school for INT and PNG.

Overall, children at the International Primary and Community School sites answered 69.5% vs. 64.0% of the mathematics exercises correctly. Reading means were 96.5% and 80.7% correct respectively. Comparisons between the Papua New Guinea and United States sites follow a similar pattern, though no language assessment was administered at the California site.

Table 6

ACHIEVEMENT SCORES FOR US ELEMENTARY AND PNG COMMUNITY SCHOOLS
PMAT 2 (%)

Years of Schooling	PMAT2[3]	
	US[1]	PNG[2]
4	59.9	52.6
6	78.1	64.3
$\bar{X}$	69.0	58.5

1. United States site – grades 3 and 5 plus one year kindergarten.
2. Community School sites - grade 4 and 6.
3. PMAT2 was administered five months after the start of school for US and PNG students.

On an average, United States students correctly answered 69.0% of the PMAT2 items, while the Community School students achieved a mean of 58.5% correct. While we didn't test for significance, the small difference in achievement means seems far more encouraging than previous crosscultural comparisons would lead us to believe. The important difference here is that we are comparing "years of schooling" as opposed to grade levels. If we took into account the number of International Primary and United States elementary school children who attend one or more years of pre-school prior to preparatory or kindergarten, we suspect that the differences in achievement would be even further reduced. It will be of considerable interest to review the progress of North Soloman children participating in the Tok Ples Schools Project (Kemelfield, 1981). These children will have the benefit of two additional years of schooling prior to starting grade one.

Cognitive Competence, Language and Mathematics Achievement: A strong relationship appears to exist between cognitive competence, English language ability (the language-of-instruction) and mathematics achievement. Correlations between a general measure of cognitive development (COGTOT – a linear combination of five conservation and classification measures), READING and DICTATION and mathematics achievement (PMAT2) are r = 0.63, r = 0.76 and r = 0.80 respectively across the entire sample interviewed (n = 201). Memory measures afforded somewhat lower correlations with maths achievement (visual memory: objects – r = 0.28; symbols – r = 0.22 and memory-space r = 0.42).

Memory skills seem to play a more significant role in the early years since the correlations between memory measures and maths achievement scores diminish with years of schooling. The opposite seems to hold for language and cognitive competence. As the mathematics content becomes more complex and the symbolic load increases, more successful students seem to rely less on their visual memory skills and more on their language abilities.

Table 7

CORRELATION OF MATHEMATICS ACHIEVEMENT WITH SIX COGNITIVE, MEMORY AND LANGUAGE MEASURES

Grade Level	COGTOT (r)	VM1 (r)	VM2 (r)	MS (r)	READ (r)	DICT (r)	PMAT2 ($\bar{X}$ %)
2	0.38	0.33	0.24	0.25	0.26	0.32	29.6
4	0.39	0.10	0.15	0.09	0.60	0.37	52.7
6	0.61	0.25	0.05	0.45	0.58	0.53	65.3
$\bar{X}_{total}$	0.63	0.28	0.22	0.42	0.76	0.80	50.9

r = pearson-product correlation coefficient.

The results of a multiple regression analysis provide further evidence of the importance of language and cognitive development in mathematics learning. Taking GRADE into account, READING, DICTATION and COGTOT accounted for over 80% of the variance in the PMAT2 scores for both males and females. Short term memory-space seemed to play a more important role for girls than boys. Visual memory contributed little to the regression equation.

On the whole the implications of this result are encouraging. Though relatively innate cognitive development and memory skills seem to contribute to successful mathematics learning in the early grades, language competence, which can be enhanced regardless of educational history, seems far more important in the development of mathematical concepts in the upper grades. Whereas measurable changes in cognitive development are relatively difficult to effect, language competence can be addressed directly with a high potential rate-of-return relative to mathematics achievement.

A transitional bilingual program for grades one and two, along with enhanced English language instruction in grades three and four, should be given prompt and careful consideration. The curriculum development effort currently underway to upgrade language instruction in the community schools should directly address the latter concern. Decisions regarding vernacular language instruction during the initial year or two of schooling will require policy level discussions and small scale piloting before the feasibility of implementing such a plan on a nation-wide scale can be determined.

In summary, the results of the correlation and regression analysis indicate that years of schooling, language ability and cognitive development are highly related to mathematics achievement. Improving the level of language competence and enriching the classroom environment with appropriate concrete and visual aids to more effectively exploit existing developmental abilities (Souviney, 1980) would go far, we believe, in improving the standard of mathematics achievement at the community school level.

Lesson Implementation: In addition to administering the cognitive and achievement instruments described above, extensive field-notes were compiled by the classroom observers. Significant classroom events were documented over the entire six week trialling period (Gearhart, 1980; Johnson, 1980; Levin, 1980; Lineberger, 1980; Rowe, 1980). In reviewing the observers' notes, several problems became apparent which seemed to detract from the quality of instruction at the majority of sites. The problems fall into three general categories:

1. Instructional materials
2. Classroom management
3. Subject matter content.

Instructional Materials: All the teachers had some difficulties coordinating the various elements associated with the lessons. Each teacher responded to the challenge in his/her own way and with varying degrees of success. The most prevalent problem involved the preparation, distribution and storage of learning aids. Those aids prepared by the IMP staff (die-cut cardboard base-10 materials, coins and kina cards, measurement devices and squared paper) were all shipped to the sites beforehand. These materials were for the most part punched-out by the teacher and packaged in the envelopes provided prior to the beginning of Term 3. No serious problems occured.

However, difficulties did arise with materials designed to be prepared by the children themselves. The time-seriation cards in grade two proved to be too difficult for the children to trace or draw. The resulting lesson took far longer than was justified. Attempts to circumvent the problems by using words instead of pictures were successful at two of the sites. One teacher reproduced copies of the worksheet for each student and the lesson proceeded as planned. Duplicating machines were available at only two of the schools. Two teachers suggested that sequence stories could be drawn by the children during art or language class and used in maths for seriating timed events.

Children, especially in grade two, spent considerable time drawing place-value tables on squared paper in preparation for practice exercises. Though the tables proved useful in helping the children develop and practice place-value and arithmetic skills, an unacceptable amount of time was required by grade two children in setting out their work. One of the causes seemed to be that the children had been instructed to be very accurate in their drawing and writing. In this case such behaviour greatly reduced the time remaining for arithmetic skill practice – the primary objective of the lesson. Upper-grade children, who had developed greater dexterity, had little difficulty setting out their exercises on squared paper.

Unless children can be encouraged to sketch the place-value tables more quickly (even at the expense of accuracy), the use of consumable worksheets should be considered at least for number work in the lower grades. A small booklet of worksheets (approximately 64 pages) could be produced locally and supplied to each child in rural schools. Urban schools could duplicate the worksheets at the school site minimizing cost and distribution problems.

In grade four, students were asked to cut out 45 squared paper multiplication blocks. These materials took from one to four class periods to prepare. Though they were used for several lessons and in general proved useful in developing and practicing the multiplication table, the time required to actually produce the aid seems unjustified. The aid could be easily produced at the Department of Education Materials Production Centre and distributed to schools for use as flash cards.

In grade six a similar problem occured with the production of place-value number cards. Again these materials proved to be useful aids but the time required to construct them did not seem justified.

Classroom produced learning aids can certainly be useful in teaching difficult concepts. The time and expense involved in their construction, however, must be balanced against potential utility. If the aid is to be used in only one lesson, preparation time must be reasonable or at least construction must take place outside of class-time, unless of course other instructional objectives can be met at the same time (eg. learning to use a ruler and scissors).

Classroom Management: Several teachers initially experienced considerable difficulty in distributing aids and materials during the lessons. The process required an excessive proportion of class-time during the first two weeks. The situation improved considerably when teachers began to give students the responsibility for distributing materials while they prepared the board for the lesson introduction. If the teacher was working in one room (the normal situation) as opposed to dividing his attention between three classrooms, the materials could be stored in the classroom and monitors could be assigned to distribute aids and materials at the appropriate times. Simple manila envelopes helped keep the student sets of base-10 materials and similar aids organized for easy distribution. Materials of this type could be mailed directly to schools in their storage envelopes. Storage will continue to be a problem in bush schools because of the damp climatic conditions. A water-tight plastic container would go far in protecting the cardboard aids.

Another classroom management problem involved organization for small-group instruction. Group work (two to six students) seemed to be an effective means of engaging children in skill practice games and concrete experiences with learning aids. Teachers initially experienced some difficulty effecting the transition between the large group lesson introduction and subsequent small group follow-up activity. Teachers often attempted to introduce an activity with the children already broken into groups. This situation frequently caused confusion since the groups lacked understanding as to how to proceed. The teacher then had to give basic instructions to each group in turn. This process caused considerable disruption as groups waited for instructions from the teacher.

The problems were alleviated by suggesting that the teacher consistently begin each lesson with a large group demonstration involving the entire class working through the same exercise or game all together. When most of the children demonstrated an ability to carry out the process on their own, the class then broke into groups with a leader appointed at each to distribute materials. The teacher then visited each group starting with those that experienced the greatest difficulties in the past. If general problems became apparent the teacher once again reassembled the whole class for a demonstration to clarify the situation. At the end of the lesson, the whole class reviewed the day's progress. A simple three-step plan emerged:

1. Whole-class demonstration – all students engaged in the same activity.

2. Small groups formed after the majority demonstrate understanding of procedures – groups work on the game, activity or exercise. Students work independently if warranted by activity. Teacher reinitiates whole-class discussion if general problems arrise.

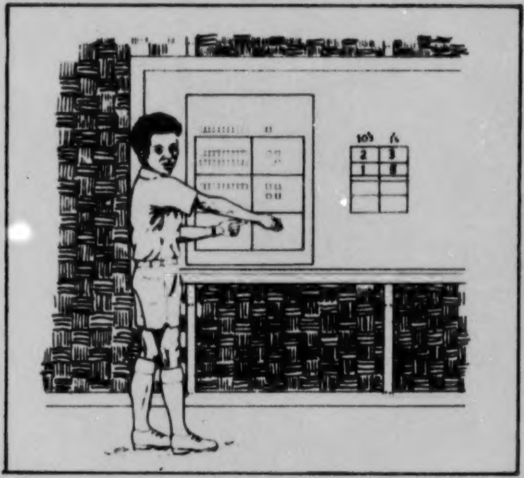
3. Whole-class review at the end of period.

One major oversight with regard to instructional materials involved difficulties experienced by teachers in displaying appropriate manipulations of the learning aids during whole-class demonstrations. Teachers made do with sketches on the chalkboard but the process of sketching base-10 models for number operations was time-consuming and somewhat more abstract than the actual concrete manipulations. We have attempted to alleviate this problem by introducing a magnetic display board. A piece of galvanised sheet-steel (50 cm x 100 cm) painted with green chalkboard paint made an excellent surface on which the teacher could chalk place-value tables and manipulate magnetized base-10 materials, coins and other aids. One or more small pieces of rubber magnet strip removed from the gasket of an old refrigerator door was glued to each cardboard piece. The display stands on the chalkboard tray. Place-value tables can be drawn on the chalkboard next to the display to carry out the corresponding symbolic manipulations.

If sheet steel is not available, the side of a metal cabinet can be painted and positioned next to the chalkboard. We found this system to be a most useful and inexpensive visual aid wherever old refrigerators and sheet metal can be found locally.

Figure 3

Magnetic Display Board



Overall the activities and instructional aids were well received by the teachers and effectively utilized by the students. The reasonable production and shipping costs associated with the materials should keep initial investment and replacement within limited budget constraints. The die-cut cardboard manufacturing technique should have a wide application in other subject areas as well. A stencil map of Papua New Guinea has already been approved for trial distribution. Die-cut cardboard aids along with a magnetic display board provide an inexpensive, versatile visual display system for classrooms even in the most remote regions of the country.

It is important that all instructional materials be supplied with a simple teachers guide keyed to the course syllabus. The guide should be prepared with the idea that it will be used by inspectors, headmasters, senior teachers and curriculum personnel as a basis for inservice instruction for practising teachers.

Finally a general problem encountered by many of the teachers involved ongoing evaluation of individual student progress. Formal and informal assessment of student achievement varied across sites. With the possible exception of the WHP teacher, the teachers were far from consistent in their efforts to determine the success of individual children in meeting lesson objectives. Rarely were individual students asked to respond to questions or observed while working in small groups. Little ongoing evaluation of student understanding took place during the course of instruction. The teachers generally characterized a successful lesson as one that progressed smoothly and in which all the material was "covered".

Teachers seemed to interpret chorused responses from the class as appropriate measures of understanding. Few criterion-referenced tests were administered by the teachers. Term tests were set about four times each year in order to compare overall achievement. The results seemed to serve primarily as a means of categorizing children, especially in the upper grades. They were rarely used as an aid in determining what specific skills individual students were lacking, as a basis for altering instruction, or as a criteria for forming appropriate instructional groups.

Clearly a series of brief (5 to 8 exercises) of criterion-referenced tests should be included in any planned textbook. The tests should appear in the text and be administered every week or two. They should be designed in such a manner as to encourage the teacher to use the results in planning future instructions. A simple record-keeping system should be described in the teacher's guide to help teachers keep track of individual student progress.

Topic or term tests could also be included to provide broader indicators of achievement and placement. Because of the difficulty in analysing the larger number of items and the length of time between setting for these term exams, it is unlikely that the results can be effectively used to benefit individual understanding of mathematics. It would be inappropriate, in our estimation, to attempt to use topic or term tests for the purpose of making class-level instructional decisions.

Subject Matter: Based on the results of our observation and testing, several changes in the current community school syllabus seem advisable. First, we feel strongly that the current stress on multibase arithmetic is inappropriate. Conceding that Dienes' multiple representation learning model has considerable theoretical support when applied under ideal instructional conditions, we contend that the application of the theoretical model to actual classroom use has met with little objective success in Papua New Guinea. Misunderstandings regarding the purpose of multibase arithmetic abound. Those teachers who possess a good grasp of the methodology often treat each base as a mastery objective rather than interim steps leading to base-10 operations.

Aside from the argument as to whether the method is effective in teaching computation, the fact remains that the multibase blocks necessary to effectively implement the program are for all intents and purposes "extinct" in Papua New Guinea. Substituting the more symbolic representation of exchange games using sticks, leaves, stones and shells is at best a poor substitute and at worst may simply increase the already overwhelming amount of disconnected school talk to be memorized.

We suggest as an alternative the development of numeration focussing almost exclusively on base-10 operations with perhaps base-3 and base-5 exchange games introduced early in the development of place-value. Number and counting should be introduced using one or two body and tally counting systems indigenous to Papua New Guinea. Structured base-10 materials (die-cut cards or locally produced seed-canoes), coins and squared paper arithmetic provide the necessary developmental transition to symbolic arithmetic. All algorithms should be developed with consistent reference to place-value and regrouping. This process should provide a consistent basis for whole number and decimal work (Souviney, Keyser and Sarver, 1978). Ratio fractions should be introduced to provide the necessary language for defining partitioning, equivalent families and the introduction to decimals. Operations with ratio fractions should be kept to a minimum (addition and subtraction with like denominators, multiplication and division of a fraction by a whole number).

We also recommend a change in emphasis regarding the development of set-theoretic and relational concepts. Rather than focussing on the underlying class or logical structures we suggest the curriculum directly address the surface language behaviours (English vocabulary and grammar) necessary for effective communication in mathematics. This suggestion is more a change in perspective than content. We envision employing activities similar to those in the current curriculum used for developing relational concepts of comparing, ordering, classifying and predicting. The difference lies with the manner in which the teacher describes the purpose of these experiences to himself and to his students. The objective becomes one of developing language skills (the value of which is already appreciated by the teacher and students) as opposed to making explicit the ideas underlying the logical structure itself (eg. clock games as models for cyclic groups).

Measurement and geometry seem fairly well developed in the current curriculum. The introduction of metric units should be coordinated with the science syllabus and should be phased in during grades four, five and six. Comparison activities should be used to introduce each measurement attribute (length, area, volume, weight, time, temperature, speed). Locally developed units of measure (either school based or traditional units) should be used to extend the notion of measurement beyond simple comparison and ordering. Finally metric units should be introduced as standard units of measure (Keyser and Souviney, 1980; Hughes, 1981). For practical purposes litre measures of volume are preferred over cubic units (eg. cm^3, m^3). We also feel the benefit of making a distinction between mass and weight is probably not worth the effort at this level. We suggest simply using the term **weight** throughout.

Geometry should progress from topographical concepts such as **inside** and **outside** to enclosed polygons, shapes, tesselations and patterns, the study of triangles and parallels, solid figures and the conventions of perspective drawing. This latter topic has received considerable attention in research carried out in Papua New Guinea (Bishop, 1979; Clements and Lean, 1980) and should be an important objective associated with geometry in grades four through eight.

The final strand which should be represented throughout the syllabus is problem solving applications. Application problems are characterized by relevance to everyday life and generally involve bringing one or more well-defined measurement or number operations to bear on elements given in the problem description. Often we describe the problem in story form where all the necessary information is embedded in the vocabulary and the language structure. The ability to solve story problems is closely tied to language skills. Other times data must be extracted from the environment in order to effect a solution. Of the five strands, none are as important or as poorly understood as problem solving. A three step process should be employed to assist children with solving mathematics application problems:

Step 1. Give the solution to a story problem and ask the student to identify the phrase that indicates what operation to use.

Problem: Venna has 6 toea. Hai has 10 toea. How much money do they have altogether?

Hint: You need to **add** to solve this problem. What word(s) tell you to add?

Answer: How much altogether?

Step 2. Ask the student to determine what operation to use to solve a problem **without** actually computing the answer.

Problem: Twelve people want to go to Loloata Island. Each canoe carries only 4 people. How many canoes are needed for the trip?

Answer: Divide.

Step 3. Have the students solve the word problem using the information given.

Problem: A truck can carry 750 kilograms of cargo. A bag of coffee weighs 50 kilograms. How many coffee bags can the truck carry?

Answer: $\begin{array}{l} 15 \text{ bags} \\ 50\overline{)750} \end{array}$

Beginning problems should be designed to be solved in one operation, with all the necessary information included. Later, problems requiring two or more operations can be attempted. Extra information not used in the solutions should be included later as a distractor. Problems should be drawn from all the content strands: number and operations, measurement, geometry and mathematical language (logic, sets and relations). Aids to problem solving such as sketches, graphs, estimating, trial and error, looking for patterns and functions should be systematically introduced (Souviney, 1981).

Textbook Production: The results of the current study offer convincing evidence that the teachers involved were capable of effectively coordinating student activity books and learning aids. There were, however, definite limits as to the number of elements the children were capable of managing efficiently. The teaching suggestions provided for each lesson were used by all the teachers on a daily basis for programming purposes and during the lesson implementation. Teachers generally praised the specific hints and suggestions though there was a consistent request for more worked examples.

Some confusion seemed to be caused by our attempt to provide complete stey-by-step instructions for each lesson. For example, in one exercise the numbered steps for the teacher did not correspond with the student exercise numbers. One teacher read the instructions verbatim to the class. For example: "Number one. Look at your worksheet. Number two. How many fish does the man have?" The children looked at worksheet problem number two instead of problem number one. They were confused, along with the teacher, for the remainder of the lesson. Though only one of the five teachers experienced this difficulty, the example points out the problems associated with writing a teaching "script" that, when read to the children without interpretation, conveys the appropriate meaning.

Though we were not attempting to "teacher proof" the lessons, our experience suggests that the curriculum writer must get into the playwrite business in a big way, or avoid giving the impression that the carefully sequenced set of instructions must be followed precisely. Clusters of directions addressing critical sub-elements of lesson procedures might be more appropriate. Subsequent synthesis of these key elements is then left to the teacher's judgement. Attempting to circumvent the teacher in such matters has, time and time again, been shown to be unsuccessful. Sets of written instructions cannot substitute for good inservice education and teaching experience.

From our experience it seems clear that teachers and children, even from the most remote sites, would benefit greatly from the prompt introduction of an appropriate mathematics textbook. The content should reflect the rich cultural heritage of Papua New Guinea and address concepts which will be required for life in this rapidly developing nation. It seems vital that students be prepared to contribute effectively to village development should they not be selected to go on to secondary school. Likewise the needs of the growing percentage of children who are privileged to continue their education cannot be ignored.

Kuperus (1980) concludes from work carried out in Cameroon, Africa, that since the vast majority of children in developing countries terminate their formal education after five or six years, the entire enterprise must be geared to preparing children for effective social and economic participation at the village level. Though stress must be placed on functional mathematics literacy, sufficient structure must also be present in the conceptual development of the content to support requirements of subsequent mathematical development necessary in commerce and secondary education. In other words, though it is vitally important to incorporate relevant features of community development into primary mathematics education (eg. designing and constructing rain water tanks, planning a trade store business, book-keeping for cash crops such as copra, cocoa, coffee, tea) these functional aspects of mathematical application are not sufficient in themselves to consitute a mathematical curriculum. The functional activities would form a collection of unrelated ideas without some attention being paid to the underlying structure of number and measurement systems, regularities and patterns found in computation and geometry and the powerful medium of communication and prediction offered by graphs and statistics. Clearly the issue of poor application of problem solving skills will remain unaddressed by a curriculum comprised **exclusively** of functional applications.

Alternately, a program of instruction which selects activities exclusively on the basis of elucidating the underlying logic and structure of the mathematical content seems totally unacceptable. Not only will the resulting knowledge be virtually untransferrable to the village development setting, without a real world context precious little learning is likely to take place at all.

In general, relevant education literature indicates that the introduction of **appropriate** textbooks has a significant effect on mathematics achievement (Comber and Keeves, 1973; Skukla, 1974; Walker, 1976; Castro and Sanguinetty, 1977). The introduction of locally produced texts seems particularly important in the Papua New Guinea context. Wilson (1978) reported that one of the primary successes associated with the implementation of locally produced curriculum materials in the Caribbean region was the vehicle it provided for inservice training. Many of the teachers involved in the development, trialling and implementation of the secondary text materials experienced significant long term changes in their own classroom behaviours. Based on such a philosophy, curriculum development in Papua New Guinea would serve the dual purpose of providing much needed instructional materials at an affordable cost as well as upgrading the qualifications of the teachers involved. Though the numbers involved initially might seem insignificant (say 20 teachers per grade level), when one includes teachers employed in the trialling of materials, as much as 10% of the teaching force could be directly involved. This process has the added advantage of ensuring a higher rate of acceptance once final implementation is underway.

Results from the current study indicate that the student activity books ameliorated to some extent the problems associated with non-native language instruction for children in remote-rural areas and for grade two students in general. These groups showed greater achievement gains than older and/or more urbanized children. We infer then that a textbook with an appropriate language load would enhance school achievement, particularly in remote-rural areas where current teaching conditions and lack of materials interact with poor English skills to create an imbalance in mathematics achievement.

Plans for the Future: A recommended set of grade level behavioural objectives has been organised into the following five content strands (Appendix II):

1. Number and Operations
2. Mathematical Language
3. Measurement
4. Geometry
5. Problem Solving Applications

This set of objectives is offered as a starting point for revising the current community school mathematics syllabus prior to planned textbook production. We attempted to structure the content objectives in a manner consistent with observed development and achievement levels of children in Papua New Guinea. Efforts were made to articulate the community school objectives with those of the new grade 7 and 8 textbooks (Britt, 1980; Hayter, 1980). Clearly the task is not completed. With generous World Bank support textbook production for grades four, five and six is about to get underway (Appendix II). A proposal has been put forward to engage the joint efforts of the Department of Education, UNDP/UNESCO and UNICEF in producing comprehensive teacher handbooks for grades one, two and three. As a resuit of this effort, the feasibility of developing student materials for grades two and three, and perhaps grade one, should be assessed with a view towards producing lower-grade textbooks by the end of the decade.

CONCLUSIONS

1. Mathematics and language achievement varied significantly between the five schools tested.

2. Grade two children exhibited mathematical achievement gains twice those for grades four and six.

3. Significantly more growth took place for all sites during the six weeks trialling period than retention period.

4. The variance associated with mathematics achievement scores diminished over the trialling period indicating that the student with low scores initially experienced larger gains in achievement scores than their higher scoring peers.

5. Of all the language and cognitive measures administered, English language competence (the language of instruction) exhibited the strongest relationship with mathematics achievement.

6. A general measure of cognitive ability exhibited a strong relationship to mathematics achievement (especially in grade six) though somewhat less than language competence.

7. In general all cognitive and language indicators were negatively correlated with growth in mathematics achievement indicating that children with the poorest skills initially gained more over the period examined than their higher scoring peers.

8. On the average students correctly answered 63% of the appropriate grade level objectives. The percent is somewhat higher for grade two, decreasing for grades four and six.

9. On the average 34% of the students tested attained an arbitrary mastery level of 80% correct responses on grade level objectives. The percent is somewhat higher in grade two, decreasing for grades four and six.

10. Students exhibited substantially higher levels of achievement relative to number and operations, measurement and mathematical language than problem solving applications.

11. Highly perceptual concrete materials are useful in developing key number and operation, measurement and classification concepts. Only materials that are actually available in the vast majority of the classrooms should be incorporated in future textbooks and teacher handbooks. Some vital learning aids will most likely need to be produced centrally and distributed to each school on a regular basis. A minimal set of aids should include: die-cut cardboard base-10, coins and attribute materials, measurement instruments (metre stick, pan balance and mass pieces, litre container, large cubes painted with chalkboard paint, trundle wheel), squared paper (1 cm^2) exercise books and a magnetic display board.

12. Examples of counting systems and traditional measurement techniques indigenous to Papua New Guinea should be incorporated into the introductions of appropriate concepts in number and operations, measurement and geometry.

13. A three step instructional procedure – concrete model, pictorial representation, symbolic manipulation – was effectively employed by project teachers when introducing number and operation concepts. The technique stressed place-value as a unifying concept and concentrated on base-10 operations.

14. The inclusion of multibase arithmetic in the primary syllabus is not required for the effective development of base-10 computation skills. Without the availability of multibase blocks, its inclusion may even be detrimental to the eventual development of arithmetic skills.

15. Student activity books were effectively used in the project classrooms. Teachers and students would benefit from the prompt introduction of an appropriate student textbook.

16. The teachers involved in the study were able to benefit sufficiently from a two-week inservice course to effectively implement student activity books and learning aids adapted from the current Mathematics for Community Schools program.

17. Inservice courses should focus on implementing specific curriculum products as opposed to addressing general pedagogical and subject matter competencies.

18. A knowledgeable individual at each school (headmaster, senior teacher or inspector) directly responsible for the mathematics curriculum materials, significantly contributed to the effectiveness of the implementation effort.

19. An efficient line of communication between provincial and/or national curriculum officers and teachers in the field contributed significantly to the effectiveness of the implementation effort.

20. The involvement of practising classroom teachers throughout the curriculum development exercise greatly simplified the implementation of the final product. The more teachers can be involved in the writing, trialling and inservice aspects of the project, the greater acceptance the product will receive once it reaches the classroom. The Maths Groups and the Port Moresby Teachers Inservice College should

play a key future role in ensuring that teachers are intimately involved in the entire curriculum development enterprise.

21. Project teachers in general exhibited limited abilities in evaluating student progress. Those tests that were administered by the teachers were used to order students for the purpose of grading and selection. The information was rarely used to assess individual student needs and/or make subsequent instructional decisions. Frequent criterion-referenced tests should be incorportated into future text and teacher materials with clear instructions as to how to interpret the results to aid in grouping students for revision and enrichment work.

RECOMMENDATIONS

1. Officers from appropriate educational institutions should review the current Mathematics for Community School syllabus with the intent of simplifying the description of teaching objectives and matching instructional expectations with the availability of instructional materials and teacher competence.

   a) Organize the subject matter objectives into five strands:

      1. Number and Operations
      2. Mathematical Language
      3. Measurement
      4. Geometry
      5. Problem Solving Applications

   b) Develop a set of minimal behavioural objectives for each grade level.

   c) Eliminate the systematic use of multibase arithmetic as the basis for the development of base-10 number and operations.

   d) Stress the use of structured base-10 materials and place-value throughout the development of whole-number operations.

   e) Give special attention to developing appropriate problem solving skills at all grade levels.

   f) Incorporate an instructional model involving three modes of representation:

      1. Concrete — concept development
      2. Pictorial — transitional development
      3. Symbolic — skill development

   g) Initiate a study to investigate the relationship between competence in the language-of-instruction (English) and mathematics achievement, especially in grades three to five.

   h) Institute a policy of assigning, wherever possible, vernacular speaking teachers to grades one and two. If no appropriate teachers are available secure the services of local school leavers to serve as teaching assistants for grades one and two, funded by local school fees.

   i) Initiate a study to investigate the effectiveness of the currently used transformational techniques in meeting geometry objectives at the community school level.

2. At the earliest opportunity, develop appropriate student textbooks, learning aids and teacher support materials for all grades.

   a) Student textbooks should be produced for grades four, five and six. After more is known about the language requirements of early mathematics learning, student textbooks, and perhaps consumable workbooks, should be provided for grades two and three and possibly grade one. A detailed teacher's guide should be provided for each textbook implemented.

   b) Until appropriate textbooks can be made available, comprehensive curriculum handbooks for teachers should be produced. One handbook should be produced for each of grades one, two and three providing detailed lesson plans, evaluation materials and background information for the teacher.

   c) Examples of counting systems and traditional measurement techniques indigenous to Papua New Guinea should be used to introduce key concepts throughout the curriculum.

   d) Problems based on situations commonly found in everyday Papua New Guinea life should provide the context for mathematics applications. Such problems offer the most promising mechanism for realising the dual goals of mathematics for community life and mathematics for higher education.

   e) Criterion-referenced mastery tests should be included in student textbooks and curriculum handbooks for teachers. These tests should be designed for easy administration and interpretation so teachers will frequently use them as a basis for making instructional decisions.

   f) A minimal set of teaching aids should be centrally produced and distributed to all schools on a regular basis, especially schools in rural areas. We suggest providing die-cut cardboard base-10, coins and attribute materials, measurement instruments, squared paper exercise books and a magnetic display board for each teacher.

   g) Practising teachers should be intimately involved with each state of curriculum development – syllabus review, materials development and inservice education – with leadership provided by the Department of Education and additional expertise recruited as necessary. The entire development exercise should be considered as an ideal opportunity to develop human resources throughout the teaching force and Department of Education.

3. Allocate resources currently assigned to staff development to fund a specific inservice program designed to implement the mathematics textbooks and teacher handbooks.

   a) Ongoing cooperation between the Staff Development Unit and the Curriculum Unit is fundamental to the success of any national implementation effort. The Staff Development Unit and the Curriculum Unit should engage in a long range budget planning exercise early in the development schedule of any new curriculum product to ensure an adequate implementation inservice program can be mounted and sustained.

b) The Department of Education should assemble key curriculum inservice personnel from each province and conduct an intensive inservice leadership training program. The individuals in turn would be responsible for training groups of headmasters, senior teachers, and inspectors who would then supervise the actual implementation of the materials by classroom teachers. The key to success is to ensure that at least one person at each school or cluster of schools is knowledgeable in the use of the materials, knows where and how to get replacements and is responsible to serve as a contact between teachers and provincial and national curriculum officers.

c) Complete classroom sets of textbooks, learning aids and teacher's guides should be distributed at the time of the inservice and adequate arrangements made to transport the materials to the province or school immediately after the national or provincial level inservice course.

d) To assist rural teachers with implementation, a year long distance-teaching inservice course using NBC radio broadcasts should be strongly considered. The course should be grade-level specific and have some professional-advancement credit associated with it, perhaps through the Port Moresby Inservice College.

SECTION II

METHOD

METHOD

The goal of the current study was to look at potential ways of changing the classroom environment to enhance students' mathematical achievement. We were interested not only in raising mean scores, but also in reducing the variance of scores within the groups considered. In other words, we were not purposely attempting to alter the environment to enhance the development of a single segment of the population (ie. the high achievers). Such an effort might significantly raise the mean achievement scores of the groups as a whole. However, it would not necessarily reflect an increase in achievement across even the majority of the subjects tested. In light of the philosophy of the community school institution – that of preparing the majority of students to participate effectively in village life while providing academic training for those who go on to high school – it seems fundamental to the entire enterprise that variance in student performance be considered as strongly as mean scores in evaluating relative success of instructional innovations.

In order to assist with the interpretation of systematic variations in achievement scores we felt it important to carefully document ongoing classroom events throughout the period of implementation. In looking ahead to the potential difficulties associated with the analysis of our test results, we anticipated that it would be useful to know what learning events may have contributed to an achievement gain. We anticipated such insight would be even more important should no gain be apparent.

From a curriculum development perspective it is as important to know why a curriculum works as simply knowing that it does work. The curriculum developers work does not end with showing the desired gains with a pilot implementation. To be effective, a curriculum must be adapted to local conditions which are certain to vary from pilot conditions in significant ways (ie. teacher motivation and competence). To provide effective advice to those responsible for helping teachers implement the curriculum, the researcher must know more than the probable increase of achievement under stated conditions. For example, it is useful to know how the **actual** lesson implementation differed from the instructions given in the teacher's guide or inservice course. Such a measure indicates the extent to which the curriculum alters teacher behaviour, depending, of course, on how much change the curriculum requires on the part of the teacher. Such information suggests which fundamental assumptions are more safely made regarding teacher compliance with the adopted instructional methods.

Such a perspective puts the teacher at the centre of the decision making process. The curriculum designer must answer the question of how much and what type of expert advice teachers will accept and apply in their classrooms. In answering such a question the researcher must do more than show significant achievement gains. Teachers would be reluctant to accept **any** curriculum that didn't offer achieviement gains or was at least more economic to implement relative to time, effort or money. To ensure even minimal success in the complex school environment the curriculum must be adapted to the actual range of competence exhibited by the teaching force, which of course is related to the magnitude of the inservice effort that can be mounted and sustained.

In light of discussion above and cognizant of the limitations such a design places on the generalizability of results, we opted to concentrate our effort and resources on five community sites.

A research associate was placed in each school to record the implementation efforts of the classroom teacher and the response of the class. A detailed field note-guide was developed by Lavin, Gearhart and Souviney (1980) in conjunction with the IMP associates and staff. The guidelines standardized the classroom observation procedures and went far in ensuring the collection of compatible data across the five sites.

Observation data was divided into four categories:

1. Curriculum Implementation
2. Language Usage
3. Classroom Interaction
4. Student Interviews

Prior to each lesson the teacher was interviewed to assess his/her understanding of the objective materials, content and methodology. The intent was to determine the extent to which the pilot teacher resource material provided information necessary for conducting the lesson. Specific questions asked by the teacher were noted and subsequently addressed by the observer. Such a procedure allowed us to discover at what points teachers had difficulty understanding lesson objectives and instructions, yet limited the observer's opportunity to provide input. We made every attempt to avoid turning these briefing sessions into a formal inservice activity throughout the six week implementation period.

After the implementation of each lesson, a formal debriefing took place. This meeting generally occurred after school or in the evening and was held in conjunction with the briefing on the next day's lessons. The content of the debriefing centred around the teacher's perception of his/her effectiveness in meeting the lesson objectives. The relative success of the lesson was explored and an attempt was made to relate the experience to that of lessons already completed. Though a briefing and debriefing took place for every lesson, detailed implementation field-notes were taken in only about three lessons per week for each grade level. The other two lessons each week were devoted to observing language usage and selected classroom interaction variables. One student was interviewed each week as well regarding his/her understanding of specific lesson objectives.

In order to document language use, standardized forms were constructed. Three categories of language were recorded, along with contextual information:

1. English – official language of instruction.

2. Melanesian Pidgin – used widely throughout Papua New Guinea, especially in the highlands and New Guinea islands.

3. Tok Ples – (talk place) local vernacular.

The language in use, the elapsed time and several contextual variables were coded for each language switch encountered during the lesson. The observer indicated whether the teacher was working with the whole class or if students were working in groups, pairs or individually. The time of the introduction, activity and discussion elements of the lesson were recorded as well. For each shift in language, the observer recorded the speaker, addressee, type of question or response, and whether the interchange concerned lesson-talk, organizational-talk or was a side remark. Coding was completed in real time though each lesson was audio-taped in order to allow the observer to fill in missing details immediately after the lesson.

A standard form was also developed in order to simplify the coding of selected classroom interaction variables. Interactional events were coded for selected lessons across the five sites. An audi-tape was made of these lessons as well, to be transcribed for later analysis. The interaction variables selected included:

A. Teacher Structuring Events

  1. Open invitation to bid student response:
    a) Chorus
    b) Callout
    c) Teacher selects respondent
  2. Individual nomination

B. Student Structuring Events (student queries)

  Teacher response:
  1. Answers question
  2. Ignores question

C. Evaluation Events

  1. Positive evaluation by teacher
  2. Negative evaluation by teacher
  3. Responsibility for evaluation redirected to student

These interactional variables were selected from the wide range of variables available based on the expected range of teacher and student behaviour in the community schools. Discussions with researchers and Department of Education personnel as well as our own observations indicated that the community school classroom could be characterized as primarily teacher directed with little ongoing objective-based evaluation to aid instruction. Evaluation was summative in nature, designed to rank students in order of achievement or to compute class means for comparison purposes. Our intent was to document who initiated interaction and evaluative events in order to assess changes in behaviour patterns over the six week trialling period, and variations between schools and grade levels. Some general results will be offered in the current report, however, detailed analysis of lesson transcripts is currently underway and will be reported at a later date.

One student from each grade level was selected, based on recommendations made by the teacher and pilot interviews, to participate in a weekly interview. Children were selected based on their interest and ability to express themselves. Though the children participating had a range of achievement scores in mathematics, no attempt was made to randomize selection. The students were asked to explain what they learned as the result of a specific lesson and any difficulties they experienced. The field-note guidelines specified a specific set of questions to be asked by the interviewer. The interview was clinical in nature, however, so the discussion often varied from the suggested format.

In addition to collecting field-notes as discussed above, achievement and cognitive development measures were also administered. Each subject was tested three times to assess mathematics achievement – immediately before and after the six week implementation period and again six weeks later as a measure of retention. Three equivalent versions of the mathematics achievement test were administered. As a measure of English language ability, a multiple choice close-type sentence completion test and a standard dictation passage was administered at the time of the retention test.

A battery of eight cognitive assessment tasks were administered in a one-to-one clinical setting to a stratified random selection of subjects from each grade level. The tasks were designed to tap cognitive competencies ranging from simple memory tasks to complex logical operations requiring a sophisticated use of language. Grade two subjects were interviewed in **tok ples** or Pidgin depending on their expressed language preference. Grade four and six used a mixture of **tok ples**, Pidgin and English, with an increasing tendency to the latter with older children. Tasks were adapted from English by the observer and a local informant using standard talk-back procedures.

These three forms of data – field-notes, achievement tests and cognitive tasks – constitute the primary data base for analysis in the current report. Additional secondary sources of data – a teacher survey, several measures of teachers' abilities and observer field reports – will be introduced as appropriate. In this section we discussed general methodological issues and data structures. Next we review the research design and its limitations.

DESIGN

The design of the curriculum trialling study involved collecting a range of data, as described in the previous section, which would be sensitive to systematic variations in achievement and classroom behaviour. The intent was to provide sufficient documentation of classroom events to help unravel the causal factors associated with observed changes in student achievement. Due to the complex research environment found in Papua New Guinea, we opted for a quasi-experimental design without random assignement of subjects. The results of the study therefore are limited in their generalizability. Similar results should be expected from other sites only to the extent to which the new site(s) resembles those involved in the current study. The five-school case study reported here offers a fairly detailed look at what might happen at similar schools in Papua New Guinea under similar conditions.

Five community schools were selected from sites involved in previous Indigenous Mathematics Project studies (Lancy, 1978). For inclusion in the study each school had to enroll grades 2, 4 and 6; the staff had to express interest in being involved; two staff members had to volunteer to participate in an inservice course and the trialling of instructional materials; the site had to represent one of the three categories of relative urbanization – extreme-rural, rural, urban; no two sites could be selected from the same province.

The project was comprised of four stages:

1. Curriculum Development
2. Teacher and Observer Inservice
3. Curriculum Trialling
4. Retention Assessment

The first stage began in November 1979 with an evaluation of the current Mathematics for Community Schools syllabus. A series of lessons was selected from those normally taught in grades two, four and six during Term 3. A set of student activity-books were developed around these lessons along with a limited number of manipulative aids and detailed teaching notes.

The second stage took place in April and June 1980. Two teachers from each school participated in a two week inservice course in Port Moresby. The objective of the course was to familiarize the teachers with the lessons and materials and to select one teacher from each school to actually use the materials during the trialling period. In June five visiting research associates arrived in Port Moresby. For two weeks we discussed and trialled plans for field-note organization, assessment procedures and reviewed the curriculum materials.

The third stage began in early July. Preliminary achievement and cognitive assessment instruments were administered by the research associates at each site. Instruction and classroom observation commenced on 14 July (the beginning of Term 3) and ended with post assessment on 22 August 1980.

Stage four began with a one week debriefing seminar immediately upon the return of the observers to Port Moresby. Field reports and recommendations for revision of materials were drafted. A final round of achievement testing was carried out in early October by the IMP staff. The following schematic of stage 3 and 4 gives an overview of important design factors.

Figure 4

DESIGN SCHEMATIC

Pre-Assessment and Clinical Interviews	Curriculum Trialling (six weeks)	Post Assessment	Retention Period (six weeks)	Retention Assessment

FIVE COMMUNITY SCHOOLS

Five community schools were selected from sites which cooperated with previous IMP cognitive research studies. Each site was evaluated according to its relative accessibility, student performance and provincial distribution. The sites selected provided a range of extreme-rural to urban settings with coastal and highland representation. Since we chose to work with grades 2, 4 and 6 the student population at each school was also taken into account.

The first school was situated on a small island just off the north coast of Manus in the Admiralty Islands of Papua New Guinea. It is surrounded by a superb lagoon protected by a reef from the open sea. It is approximately one kilometre by two kilometres in size with its highest point about two metres above high tide. Fish are plentiful and fresh vegetables can be obtained at the twice weekly market on the mainland. The current population is approximately 250 people.

Commercial flights arrive in Lorengau, Manus, several times each week. It requires an additional three hour canoe trip to arrive at the site. Accessibility was classified as difficult in that equipment and personnel had to travel by expensive (35 kina each trip) private canoe, subject to favourable weather conditions.

The school was constructed in the late 60's of locally produced cement blocks with louvered windows and corrugated iron roofing. The building is situated on the public common area along with the health aid-post, teachers' houses and a public club (a provincial experiment in village level alcohol sales). The site consists of three classrooms and a small office. The school initiates intake every other year so the student population consists of grades one, three and five one year, and two, four and six the next. For some unexplained reason there was no intake in 1979, so in 1980, grades one, four and six were available. We decided to use the school anyway since it had available more of the grade levels with which we were working than the other schools under consideration in the region.

Schooling in the area was initiated in the 1920's by the Catholic Mission at Bundralis only a few kilometres away on the mainland. Primary schooling began at the island site in the 1950's with a full compliment of grades (1–6) being instituted less than ten years ago. Currently there are two teachers serving about 90 students in three grades. Nearly all school age children on the Island (and some family members from the mainland) attend school. Most adults under 40 have some schooling. The local vernacular is the first language of all the children on the island. Pidgin is widely spoken as, to a lesser extent, is English. Manus enrollment figures for 1979 show approximately 61% of the 7–12 year old population in school.

The second site, even more remote than the first, is accessible only by small aircraft servicing the local mission at Tekin or the government station at Aksapmin, West Sepik Province. It requires an additional three hour walk through lush mountain vegetation to reach the school at an altitude of about 2000 metres. The school, playground and gardens are terraced into the side of the hill next to a small river. The buildings consist of six classrooms, an office and several teachers' houses, all constructed of bush materials except the headmaster's house. The school, built less than ten years ago, houses five teachers and 126 students in grades two, three, four and six (two second grades). Though it is difficult to make accurate estimates regarding the percent of school age cohorts attending primary school, we figure less than 50% of those under 18 years have attended school, with somewhat smaller percentage completing grade six. West Sepik 1979 enrollment figures show approximately 62% of the 7–12 year old population in school.

The local vernacular (Oksapmin) is the first language of all the children. Pidgin is increasingly spoken as local men return from work on a tea plantation near Mount Hagen. English is spoken only at school.

The community surrounding the school consists of several small hamlets with a total population of about 1800 people. The men clear kaukau and taro gardens on the almost vertical slopes of the mountains. When money is available, rice and canned mackerel are available in the trade stores to supplement the diet. Though many domestic pigs can be seen roaming the hillsides, they are eaten primarily at celebrations minimizing the usefullness of this source of protein. Many children show signs of protein deficiency and almost constant colds due to the damp, cold climate and scanty clothing.

The third site was located in the Southern Highlands, three hours drive from Mount Hagen. Though this school can now be reached by road throughout the school year, this has only recently been the case. The school was built in 1966, providing the first schooling opportunity for the 15 villages in the area. The site consists of seven semi-permanent classrooms, two bush materials classrooms, an office and storeroom, several teachers' houses, a large playground, gardens and a fish pond. Eight teachers service 291 children in grades one through six (two each of grades one and two). In the villages within one hour walking distance an estimated 90% of the school age cohorts attend school. The figure drops dramatically for more remote villages. Over the whole region less than 50% of the children complete grade six. Southern Highlands 1979 enrollment figures show approximately 51% of the 7–12 year old population in school.

The local vernacular (Imbonggu) is the first language of all the children. Some Pidgin is used in the villages. English is reserved almost exclusively for school. The primary food staple is kaukau and greens supplemented with rice and tinned fish, if money is available from basket-making or limited construction work. The only local source of protein is a few fish caught in streams and domesticated pigs which are eaten primarily at clan celebrations. Children continually show symptoms of colds though school attendance is reported as high.

The fourth school is situated approximately one half hour drive from Mount Hagen in Western Highlands Province. It is built on a flat plain at an altitude of about 1800 metres. The area has excellent soil and growing conditions providing a wide range of fruits and vegetables for sale and local consumption. The area boasts some of the finest coffee plantations in the country as well. Ancient drainage ditches, reportedly among the oldest in the world, built to enhance agricultural productivity, have been discovered close to the school.

The school was originally built at a nearby site in the early 1960's. The current structure built in the mid-1960's consists of two permanent structures containing five classrooms, an office and a store room, three bush material classrooms, several houses for teachers, two gardens and a number of coffee plants. It is connected to Mount Hagen by an all weather road and frequent public motor vehicle (PMV) service. The school is relatively well equipped with a duplicating machine, a modest library and a telephone. Two additional permanent classrooms are currently under construction as well. The students and teachers grow vegetables and coffee to sell in the local market in order to generate additional money for school equipment and activities. The eight teachers service approximately 233 students in grades one through six (two each of grades one and six).

The local vernacular (Melpa) is the first language of all the children in the area. Considerable Pidgin is spoken in the community as well. English is rarely spoken outside school. Approximately 60% of the children in the catchment area attend school. Western Highlands 1979 enrollment figures show approximately 45% of the 7–12 year old population in school.

Our final school was situated in a suburb of Port Moresby. It was built when the Tokorara subdivision was constructed in the mid-1960's. It consists of 12 permanent classrooms built on posts with louvered windows, wood floors and corrugated metal roofs. It was the only site that had full city services – electricity, running water and plumbed toilets. The teachers lived in similarly constructed houses surrounding the school. The entire site was enclosed by an eight foot woven-wire fence to reduce vandalism. The school was well equipped with a duplicating machine, small library, modest teaching aids and textbooks, a telephone and a canteen which provided hot lunches for students at a modest cost.

The community is comprised of government and industry personnel who are products of scores of villages throughout Papua New Guinea. Most of the children are from upwardly mobile families who speak English at home. Most children are multilingual when they begin school. They are generally able to speak English, mother's and/or father's tongue, Motu or Pidgin. Mostly English is heard on the playground except with the youngest children. Eleven teachers at the school serve 408 children in grades one through six (three grade ones, two each of grades two, three and four). A relatively large school, it services almost all of the school-aged children in its middle class catchment area. National Capital District 1979 enrollment figures show approximately 62% of the 7–12 year old population in school.

The uniqueness of each site is the reflection of a multitude of environmental variables. Language and cultural factors, staff experience and motivation, availability of instructional materials, accessibility and frequency of inspections, students health and family support all contribute to the relative effectiveness of each school in promoting student achievement. The five communities range widely in accessibility, language, culture and type of economy. The schools reflect these variations as well as substantial differences in the physical classroom environment. Table 8 summarizes various characteristics of the five sites.

Table 8

SITE CHARACTERISTICS

Site	Stud. N. Tot	% Fem.	% Cohort in Sch.	Classrooms			Teachers (n)	Experience $\bar{x}$ Yrs.	Elec.	Tele.	Duplicator	Min. Cost to POE (r.t.)	Hours to POE (r.t.)
				Perm.	Bush	Tot.							
MP	90	43	61	3	0	3	2	10.5	N	N	N	K 10.00	6 (canoe)
WSP	126	28	62	0	6	6	5	3.8	N	N	N	K125.00	6 (foot & air)
SHP	291	47	51	7	2	9	8	4.5	N	N	N	K 8.00	4 (PMV)
WHP	233	48	45	5	3	8	8	5.6	N	Y	Y	K 2.00	1 (PMV)
NCD	408	45	62	12	0	12	11	6.9	Y	Y	Y	K 1.20	0.5 (PMV)
$\bar{X}$	230	42	56	5.4	2.2	7.6	6.8	5.6	N/A	N/A	N/A	K 29.24	3.5

POE – Provincial Office of Education
MP – Manus Province
WSP – West Sepik Province
SHP – Southern Highlands Province
WHP – Western Highlands Province
NCD – National Capital District

Though the schools exhibit a wide variance in environmental and cultural factors, instruction at all sites followed the same syllabus with a similar number of minutes taught per week for reading, mathematics and community life. The level of teaching experience tended towards the pattern of the least experienced teachers being assigned to the most rural schools. The teachers actually involved in the trialling of the pilot materials had roughly equivalent training and experience and achieved similar scores on various measures of cognitive ability.

In this section the characteristics of the five participating community school sites were described along with background information on the teachers involved in the study. Though the sites exhibit a range of characteristics which can be used to describe schools throughout Papua New Guinea, the reader should remember that the selected sites are not necessarily a representative sample of the approximately 2000 schools in the country. Therefore comparisons with other sites will be meaningful only to the extent to which they are similar to one or more of the schools described here. Generalisations from a single site to an entire province are certainly inappropriate. In the next section we take a closer look at the student characteristics at each site.

STUDENT POPULATION

Three classrooms were selected at each site (except Manus), one each for grades two, four and six. If a school had more than one class of any of the three grades, one was randomly selected to participate in the trialling. One of the duplicate classes at four sites participated in the achievement assessment to provide controls for comparing patterns in achievement. Only the island site in Manus was unable to provide a complete complement of grade levels and a paired control class. Table 9 gives a summary of student ages for classes involved in the study.

Table 9

SUBJECT AGES

Grade	2		4		6		Control			Total Site	
Site	n	$\bar{X}$ age	n	$\bar{X}$ age	n	$\bar{X}$ age	Gr.	n	$\bar{X}$ age	n	$\bar{X}$ age
MP	N/A	N/A	22	12.5	29	13.3	N/A	N/A	N/A	90	11.2
WSP	26	11.0	28	10.9	23	14.6	2	30	9.9	126	11.3
SHP	34	9.2	32	10.2	33	14.4	2	35	8.3	285	9.7
WHP	21	7.6	45	10.9	23	12.3	6	21	12.5	233	10.0
NCD	41	8.5	36	11.3	36	12.2	4	38	11.3	408	9.7
$\bar{X}$	30.5	9.1	32.6	11.1	28.8	13.3	3.5	31	10.3	228.4	10.1

$\bar{X}_{age}$ = mean age
n = number of students

Preliminary Assessment: Preliminary achievement testing at the five sites served a dual purpose. First, the Primary Mathematics Achievement Test (PMAT–1) received initial trialling in order to workout administration procedures and investigate various format considerations. All the students in three trialling classes and the control class at each school (grades one, four and six at Manus) took the tests. The tests were scored immediately and the students ranked from high to low. Each class was divided into three strata – the top, middle and bottom third. Five subjects were randomly selected from the top and bottom for subsequent one-to-one clinical interviews. Each of these subjects was assessed using a standard battery of nine cognitive tasks. Again the preliminary assessment provided an opportunity to develop standardized administration procedures for the cognitive tasks and validate the ability of each task to discriminate between levels of competence.

In addition to the trialling of the assessment instruments, the preliminary achievement and cognitive measures provided a means of comparing the control and experimental classes in order to test initial equivalence. Table 10 lists the results of the preliminary testing carried out in April and May 1980.

Table 10

PRELIMINARY ASSESSMENT RESULTS

Site	Gr.	^{n}pmat-1	PMAT-1 %	CI	CD	CN	LC	MS	S1	S2	VM1	VM2	^{n}cog	Age $\bar{X}$ cog
MP	1	38	13.7	N/A	10.9	N/A	N/A	1.86	6.9	11.6	5.9	6.0	10	8.3
	4	22	45.2	3.7	15.0	5.0	4.5	3.07	11.5	16.1	9.8	8.1	10	11.5
	6	28	61.3	4.2	14.2	5.8	5.9	4.70	12.6	17.2	9.2	9.3	10	13.2
WSP	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	2 ctl	25	19.0	4.1	11.9	7.8	4.5	2.77	10.2	14.5	8.8	6.0	10	7.8
	4	30	36.8	5.2	14.0	8.8	4.8	4.17	11.8	16.4	8.7	9.3	10	11.7
	6	20	51.4	5.0	14.7	7.8	6.6	4.47	12.0	17.7	8.7	10.1	10	14.8
SHP	2	35	29.3	5.0	14.7	11.3	7.5	3.97	11.8	17.6	8.5	7.3	10	N/A
	2 ctl	33	29.1	3.9	14.7	12.8	5.4	3.50	11.1	14.9	7.3	4.7	10	8.5
	4	33	55.2	4.7	12.6	9.0	7.8	4.65	12.7	15.6	11.1	10.5	10	10.6
	6	33	64.7	4.9	15.0	12.4	7.8	5.26	13.0	17.8	10.1	9.5	10	14.0
WHP	2	21	21.5	3.2	12.1	5.8	6.9	2.30	11.8	14.5	6.6	6.8	10	9.5
	4	45	44.2	4.3	14.0	7.0	7.2	4.23	13.0	16.5	8.4	7.6	10	11.1
	6	25	52.4	5.7	14.5	8.1	6.3	3.43	12.4	17.4	6.8	8.1	10	12.4
	6 ctl	24	54.9	5.2	14.0	8.6	7.5	3.44	11.2	15.9	9.0	9.8	10	12.9
NCD	2	39	19.3	3.2	14.8	9.1	4.2	3.27	10.8	11.3	6.1	6.7	10	8.3
	4	34	41.1	3.6	13.8	7.9	6.3	5.50	12.2	14.1	7.2	8.4	10	10.9
	4 ctl	39	41.5	3.1	14.3	8.9	6.3	4.60	11.6	15.2	8.8	7.1	10	10.8
	6	30	58.7	4.3	15.0	9.2	8.6	5.34	13.0	18.3	9.8	8.2	10	12.4

MP – Manus Province
WSP – West Sepik Province
SHP – Southern Highlands Province
WHP – Western Highlands Province
NCD – National Capital District
ctl – Control group

PMAT-1 – Primary Mathematics Achievement Test – 1
CI – Class Inclusion (maximum score 6)
CD – Coding (15)
CN – Conservation of number (14)
LC – Logical Classification (9)
MS – Memory Space (7.00)
S1 – Single seriation (13)
S2 – Double seriation (19)
VM1 – Visual Memory – objects (12)
VM2 – Visual Memory – symbols (12)

We made no attempt to carry out cross-cultural comparisons using this data since assessment procedures were still being developed and were not standard across sites. Our analysis indicated, however, that the paired experimental and control groups within sites were not significantly different in either achievement or cognitive competence.

The mean age by grade level varied across sites. Higher age means were found in more rural sites indicating a later starting age, inconsistent attendance, or both. It was reported that girls in particular were taken out of school for a year or more to help with children or gardens at home. This phenomenon tended to increase the mean age in the subsequent grade upon their return to school.

In general there were fewer girls than boys, especially in the upper grades. There seemed to be a more even balance in more urban settings. The children were of average health for the regions in which they resided. The children living in highland areas showed chronic symptoms of colds which is not surprising considering the climate and the relative lack of shoes and clothing. Attendance was reasonably consistent throughout the year. Subjects with excessive absences were dropped from the study.

Thirty-four of the children who participated in the study from the National Capital District (11), Western Highlands Province (9) and Southern Highlands Province (14) sites were given detailed physical examinations in April 1981 by doctors A. Dietrich and A. Olsen. Their report indicated that two of the children exhibited slight vision anomalies, three had a detectable decrease in hearing, eight had ear infections, two had enlarged spleens, one had anomalous genetalia and another had extensive draining of the lymph nodes. They concluded, however, that only two of the 34 children seemed to exhibit a chronic illness sufficient to effect their school performance. No objective differences in level of health was apparent between these sites.

The project staff were particularly impressed with the motivation and eagerness exhibited by the students at every site. Even under adverse conditions – cold, damp, dark classrooms, inadequate seating; in coastal regions, hot, humid absolutely still days – the children were almost without exception wide eyed, hard working and graciously forgiving.

TEACHERS

As previously mentioned, the ethnographic design of the current study required extensive classroom observations and frequent interviews with each teacher. Initially we were concerned that teachers would be reluctant to commit their time and energy to such a project. Our fears were quickly dispelled after visiting several classrooms at each site and discussing the proposal with the staff. Several teachers at each site expressed interest in participating. It was clear that access to improved instructional aids for their classrooms and the potential for professional development contributed to their enthusiasm. We were continually impressed with the level of professionalism exhibited by project teachers throughout the eight-month duration of the study.

Two teachers from each of the five sites were selected to participate in a two week inservice course sponsored by IMP at the Port Moresby Teachers Inservice College. The individuals agreed to give up their Easter holiday and their involvement in the National Inservice Training Week in order to participate.

The level of teaching experience for the ten participants (eight men and two women, all in their twenties and early thirties) ranged from 4 to 11 years. Each had completed two years teacher training after provincial high school (grade ten). The group as a whole were seen as relatively successful teachers by their supervisors, spoke English with varying degrees of ease and planned to remain in the field for the foreseeable future. All participated actively in the two week inservice course except two; one arrived three days late due to transportation difficulties, and another missed the first week due to a death in the family.

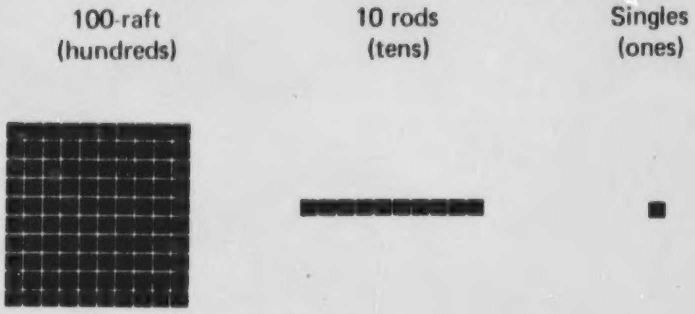
Inservice Course: The Port Moresby Inservice College was graciously able to accommodate the participants' housing needs and provided class space for the IMP Inservice Workshop (7–18 April). The course content was divided into three parts:

1. Whole numbers and operations
2. Logic and classification
3. Measurement

Most of the first week was spent developing the place-value concept and four whole number operations using base-10 structured materials. Instruction was activity-oriented with considerable participant involvement and interaction. An inservice guide (Learning to Compute, 1980) was prepared prior to the workshop and was used as a basis of instruction and independent activity. Each participant was expected to complete several exercises each evening (Monday–Thursday).

The first part of each session was devoted to participant demonstrations and questions. Much progress was made by the end of the first week. All the teachers were able to demonstrate the proper use of base-10 materials in motivating the standard algorithms for the four operations (three digit addition and subtraction and two digit multipliers and divisors). Place-value was stressed throughout the development of each algorithm. A problem was first displayed using concrete base-10 materials:

Figure 5



After several problems were solved with these highly perceptual materials, sketches or appropriate coins (1t, 10t, K1) were substituted. Finally symbolic examples were attempted on centimetre squared paper using procedures identical to the previous concrete representation. A more detailed discussion of procedures can be found in the section on Instructional Materials.

Beginning the second week logic and classification activities were explored. Attribute materials (Kina Cards) were designed specifically for use as a classification medium in Papua New Guinea. Several different classification activities were incorporated to provide practice using the cards and to develop the classification concept such as conjunction ("and"), disjunction ("or"), negation ("not") and inclusion. Activities were carried out on lap boards using venn and carrol diagrams and road systems chalked on the floor. Again the participants actively worked through all experiences planned for inclusion in the trial lessons.

A series of measurement activities were also conducted later in the week. Each measurement attribute commonly taught in the community school (length, area, volume, weight, temperature, time) was reviewed and appropriate activities discussed. A review was also made of Mathematics for Community Schools lessons which were to be included in the trial materials.

We endeavoured to provide content instruction relative to the topics the participants would be expected to teach their classes. During the course of the inservice, we modelled the instructional methodology called for in the trial teacher's guide. The participants responded extremely well to this arrangement.

In light of the time constraints (54 contact hours) and the fact that the "Teacher's Notes" and student workbooks were not available in time for the course, the participants left highly motivated for the task ahead. In general we were pleased with the competence exhibited by those who participated. The two individuals who were unable to attend all the sessions fell behind, though at least one of the two seemed to catch-up with the assistance of colleagues in the evening.

One of the two participants from each site was selected to implement the IMP trial materials at his own school. The selection was made based on the competence demonstrated during the activities and practice teaching in the course, as well as the breadth of their teaching experience. Since we planned to have one teacher instruct grades two, four and six we, as much as possible, chose individuals with experience in both upper and lower levels. The second participant at each site became responsible for logistics, communication and materials. The total cost of the two week workshop, including transport, housing and materials, was approximately K2500.

Several cognitive measures were administered to each participant. The results indicated no significant differences in mathematics achievement (PMAT), maths attitude (Aiken Mathematics Attitude Scale) or I.Q. (Ravens Progressive Matrices).

INSTRUCTIONAL METHODS AND MATERIALS

The IMP staff developed over 30 lessons to be used as a basis of instruction during Term 3 for grades four and six and 60 lessons for grade two. Each school scheduled five periods of IMP mathematics per week. Two extra maths classes were scheduled in the afternoon as well, providing extra time for completing assignments. All the lessons were scheduled for 30 minutes in length, giving a total of 210 minutes instruction per week.

Many of the lessons were adapted from the Mathematics for Community School teacher's guides. Several changes in emphasis were incorporated into the set of trial activities. In order to allow more time for the development of base-10, place-value and number operation concepts, work with multibase arithmetic was eliminated and the number of relations activities reduced. New sequences of structured activities were introduced to provide a firm base for developing algorithms for whole number operations (Souviney, Keyser, Sarver, 1978). Classification activities were adpated for the use of Kina Cards as well.

Table 11 lists those lessons adapted more or less directly from the MACS books and grade 7 "Mathematics Our Way" as well as newly developed activities included to enhance arithmetic skills (Britt, 1980).

Table 11

TRIAL LESSONS

Grade	MACS and MOW lessons	New lessons	Total (n)
2	53C–53H; 55A–55D; 56A–56F 57A–57H; 58C–58E; 58G–58H 59A–59D; 60A–60G; 61A–61E 62A–62F	53A, 53B 53I–1,2; 57I–1,2 58A, 58B, 58F	60
4	144A–144F; 145A–145D; 146A–146D; 148A–148D; 149H	149A–149G; 164A–1,2; 164B–1,2,3.	31
6	6:1–6:11; 6:13–6:15; 6:17–6:35	6:12, 6:16	35

The objectives of the lessons address the following topics:

1. Number and numeration (place-value)
2. Number operations (+, –, x, ÷)
3. Classification
4. Relations
5. Measurement
6. Problem Solving

No specific geometry lessons were planned for Term 3 and none were included in trial materials. The following table lists the number of lessons in each content area by grade level.

Table 12

CONTENT BREAKDOWN

Grade	Numeration	Operations	Classifications	Relations	Measurement	Problem Solving	Total (n)
2	25	4	0	14	13	4	60
4	6	12	4	4	4	1	31
6	5	22	0	0	0	8	35
Total	36	38	4	18	17	13	126
% of Total	29%	30%	3%	14%	13%	10%	100%

A range of lessons was selected for inclusion. Some required extensive use of learning aids such as base-10 materials with the students organized in small groups. Others involved large group discussions or independent seat work. Our intent was to document the teacher's success in implementing lessons of various configurations and subsequent student response.

Several innovative features were incorporated into the trial materials. Student activity books were produced for distribution on a one-to-one basis. A step-by-step guide was prepared for each lesson in order to assist the teacher's programming efforts. A minimal set of inexpensive learning aids was designed and produced to provide the concrete experiences called for in the Teacher's Notes. The following materials and aids were supplied to each site:

1. Student Activity Booklets (one per student).

2. Teacher's Notes (two sets per school).

3. Learning Aids:

    a) Base-10 Materials (ones, 10-rods, 100-rafts; die-punched cards – 50 sets per school).
    b) Kina Cards (attribute cards – 40 sets per school).
    c) Coins (2 cards – 40 sets per school).
    d) Wooden Cubes (dice – 20 per school).
    e) Pan Balances with mass-pieces (5 sets per school).
    f) Metre Sticks (8 per school).
    g) Trundle Wheels (4 per school).
    h) Squared Paper (1 cm^2 – 30 sheets per student).

Physical materials designed to offer optimal perceptual input for the novice learner were considered vital in the multilingual community school environment. It was envisaged that teachers who had difficulty communicating directly with children from different language groups could use structured teaching aids to help translate the mathematical concepts and processes rather than relying exclusively on symbolic examples and chalkboard drills. Three primary areas of mathematics content (excluding geometry) were addressed using various concrete aids:

1. Number and Operations (Base-10 materials, coins, squared paper)

    a) Place-value
    b) Addition
    c) Subtraction
    d) Multiplication
    e) Division
    f) Problem Solving

2. Measurement (metre sticks, balances, trundle wheels)

    a) Estimation
    b) Comparison
    c) Length, Area, Mass, Volume, Time, Velocity
    d) Metric System
    e) Problem Solving

3. Classification and Logical Thinking (Kina Cards)

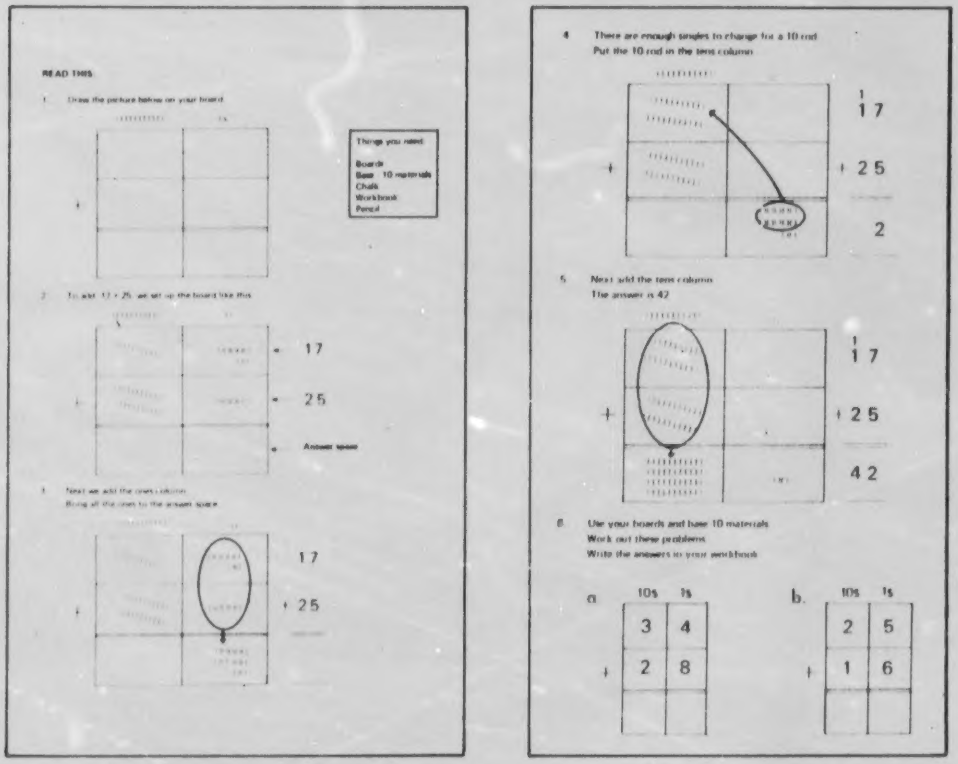
   a) Likeness and difference relations (attributes)
   b) Logical connectives (and, or)
   c) Negation (not)
   d) Union, Intersection
   e) Class Inclusion
   f) Problem Solving

The learning philosophy underlying the MACS course as well as the IMP trial materials is one of active participation on the part of the learner. The processes can best be described as one of guided discovery whereby the learners' activity constructs order out of seeming disorder. The task of developing the considerable amount of mathematical knowledge in the limited time allowed is rationalized by the consistent, unobtrusive aid of the teacher and the structure of the curriculum itself.

In the next section we review the Developmental Activity Sequence approach reflected in the trial materials. A three step instructional sequence is employed (Souviney, Keyser, Sarver, 1978) when introducing a new concept, say addition with regrouping. Through the use of structured concrete base-10 materials the procedure of making partial sums is modelled. Beginning with the ones column we effect the necessary exchange, regroup the results and repeat the cycle. The second step involves carrying out similar manipulations using coins (1t, 10t and K1) or pictures of the base-10 materials. Finally, in the last step, the child manipulates symbols only and engages in sufficient practice at this level to ensure the procedure is reasonably well automated. For example, the following sequence was included as a review for grade six students.

Figure 6

Addition Using Base-10 Materials



READ THIS

1 Draw the picture below on your board

2 To add 17 + 25, we set up the board like this

3 Next we add the ones column
Bring all the ones to the answer space

4 There are enough singles to change for a 10 rod
Put the 10 rod in the tens column

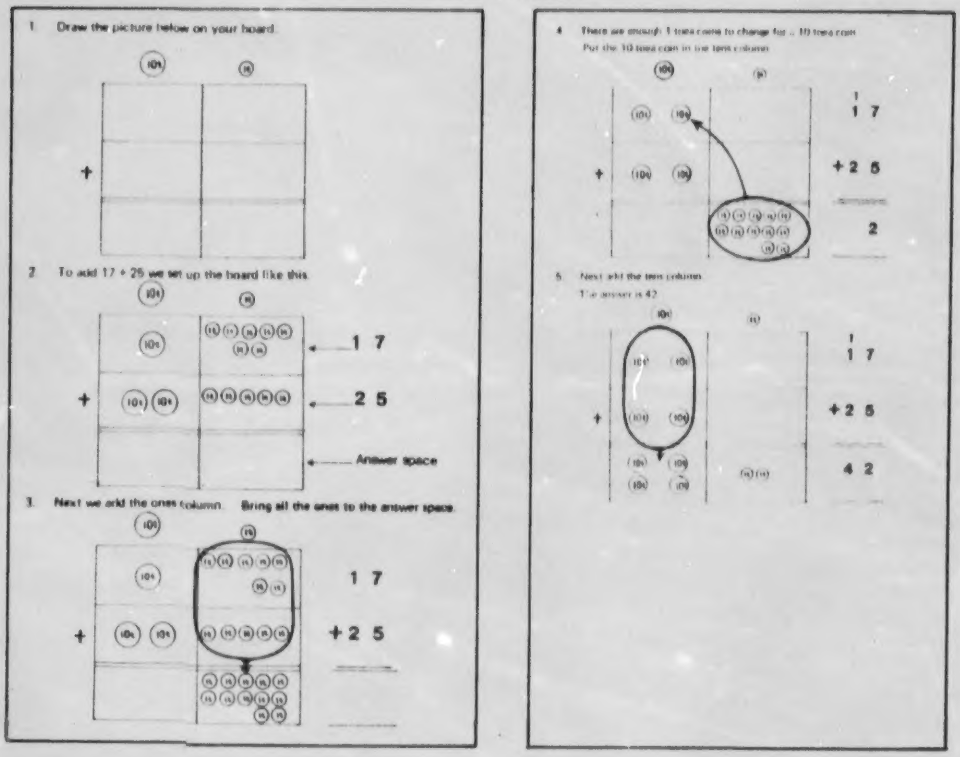
5 Next add the tens column
The answer is 42

6 Use your boards and base 10 materials
Work out these problems
Write the answers in your workbook

Similar problems are solved using coins in place of the base-10 materials.

Figure 7

Addition Using Coins


1 Draw the picture below on your board.

2 To add 17 + 25 we set up the board like this.

3 Next we add the ones column. Bring all the ones to the answer space.

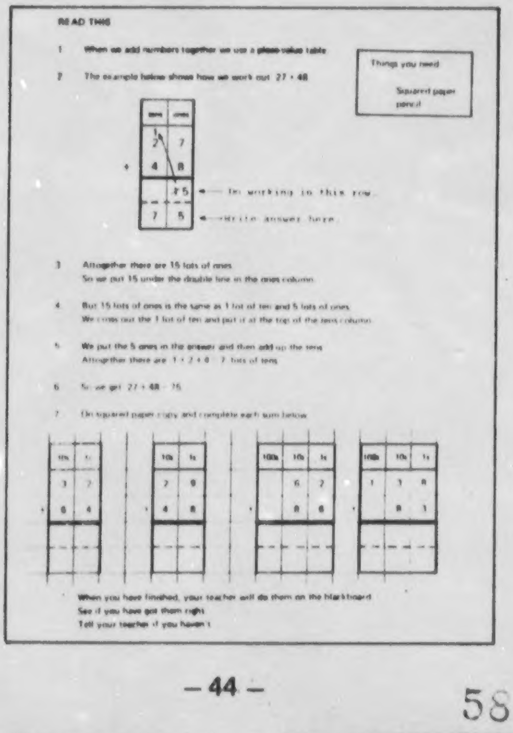
4 There are enough 1 toea coins to change for a 10 toea coin. Put the 10 toea coin in the tens column.

5 Next add the tens column. The answer is 42.

Finally symbolic exercises are assigned and are solved with the aid of squared paper to keep the columns lined up. Note that identical procedures are followed throughout the three step sequence.

Figure 8

Addition Using Squared Paper


READ THIS

1 When we add numbers together we use a place-value table.

2 The example below shows how we work out 27 + 48.

Things you need

Squared paper
pencil

tens
ones
1
2 7
+ 4 8
15
7 5

← Do working in this row.

← Write answer here.

3 Altogether there are 15 lots of ones.
So we put 15 under the double line in the ones column.

4 But 15 lots of ones is the same as 1 lot of ten and 5 lots of ones.
We cross out the 1 lot of ten and put it at the top of the tens column.

5 We put the 5 ones in the answer and then add up the tens.
Altogether there are 1 + 2 + 4 = 7 lots of tens.

6 So we get 27 + 48 = 75.

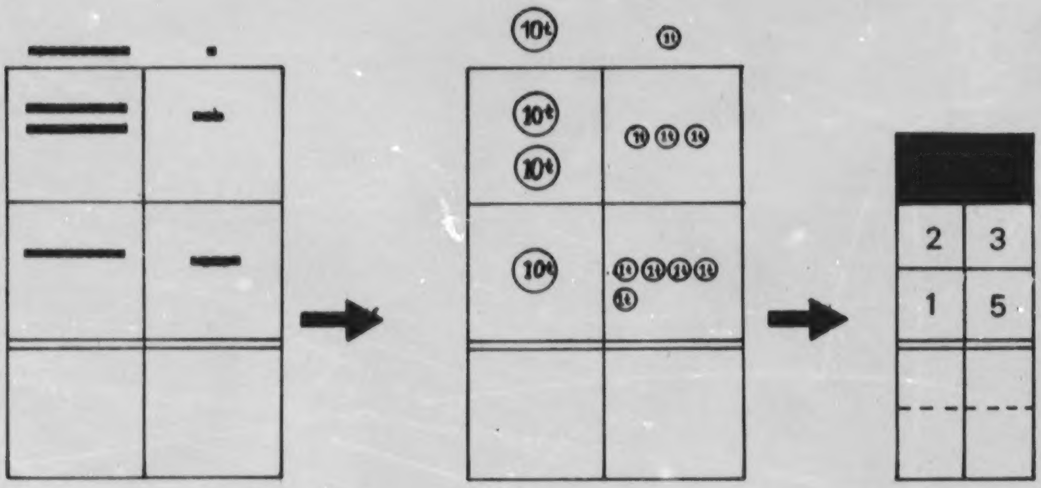
7 On squared paper copy and complete each sum below.

When you have finished, your teacher will do them on the blackboard.
See if you have got them right.
Tell your teacher if you haven't.

The concept of place-value is stressed throughout the development of the whole number algorithms. The activity pages display exercises under place-value headings. Initially the headings show actual pictures of the base-10 materials, later coins and finally the number symbols themselves.

Figure 9

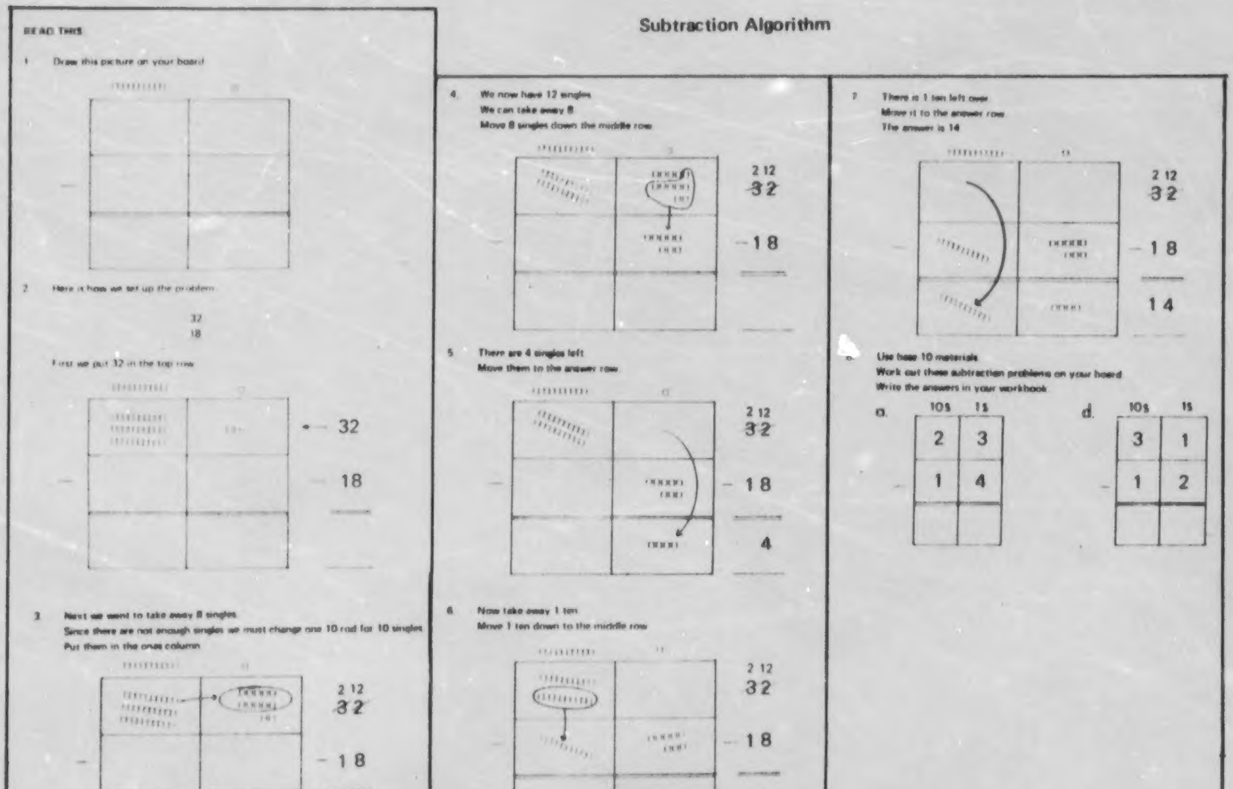
Three Stages of Representation



Each operation is developed using a similar model, though in the upper grades less stress is made on actually manipulating the base-10 materials. Teacher demonstrations and graphic representations in the student activity books are used to motivate concept development. Exercises are included at the final (symbolic) stage to ensure that the students engage in sufficient practice so that they can consistently apply the skill in the future. The three other operations are developed as follows:

Figure 10

Subtraction Algorithm



READ THIS

1 Draw this picture on your board

2 Here is how we set up the problem

32
18

First we put 32 in the top row

3 Next we want to take away 8 singles
Since there are not enough singles we must change one 10 rod for 10 singles
Put them in the ones column

4. We now have 12 singles
We can take away 8
Move 8 singles down the middle row

5 There are 4 singles left
Move them to the answer row

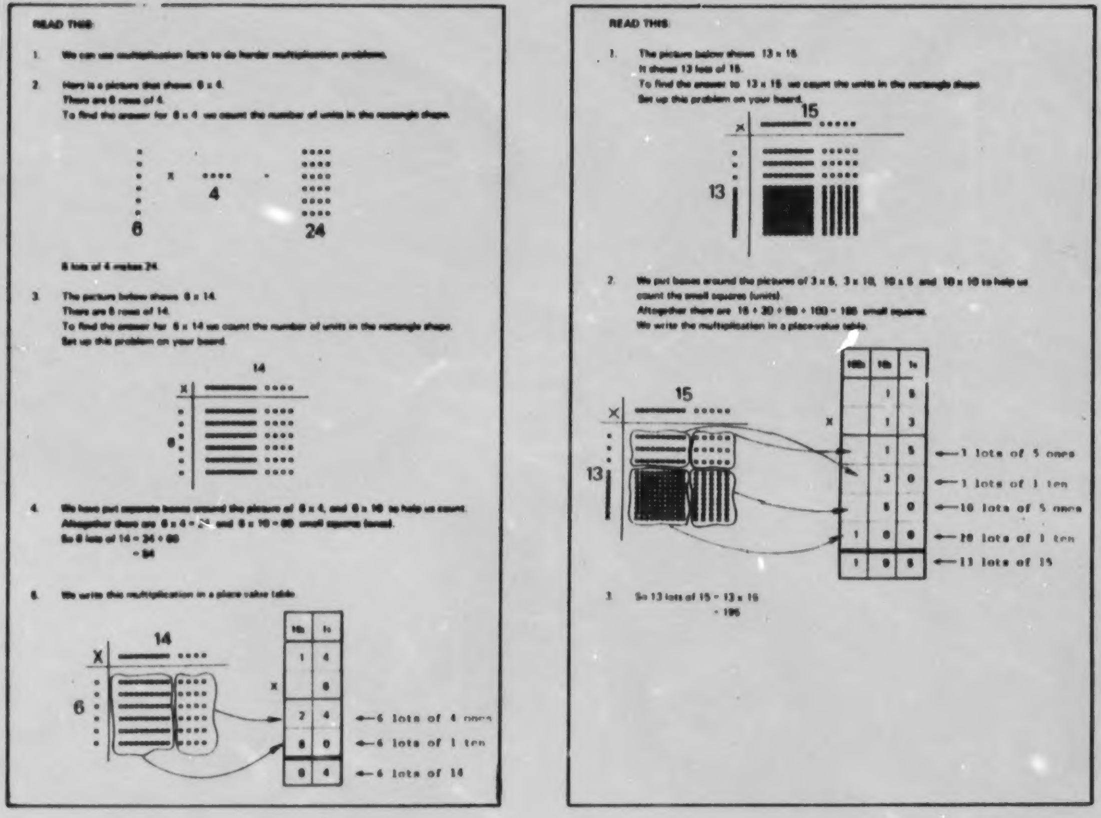
6 Now take away 1 ten
Move 1 ten down to the middle row

7 There is 1 ten left over
Move it to the answer row
The answer is 14

Use base 10 materials
Work out these subtraction problems on your board
Write the answers in your workbook

Figure 11

Multiplication Algorithm



READ THIS

1. We can use multiplication facts to do harder multiplication problems.

2. Here is a picture that shows 6 x 4.
There are 6 rows of 4.
To find the answer for 6 x 4 we count the number of units in the rectangle shape.

6 lots of 4 makes 24.

3. The picture below shows 6 x 14.
There are 6 rows of 14.
To find the answer for 6 x 14 we count the number of units in the rectangle shape.
Set up this problem on your board.

4. We have put separate boxes around the picture of 6 x 4, and 6 x 10 to help us count.
Altogether there are 6 x 4 = 24 and 6 x 10 = 60 small squares (units).
So 6 lots of 14 = 24 + 60
= 84

5. We write this multiplication in a place value table.

14
X
6
10s
1s
1 4
x 6
2 4
6 0
8 4
←6 lots of 4 ones
←6 lots of 1 ten
←6 lots of 14

READ THIS

1. The picture below shows 13 x 15.
It shows 13 lots of 15.
To find the answer to 13 x 15 we count the units in the rectangle shape.
Set up this problem on your board.

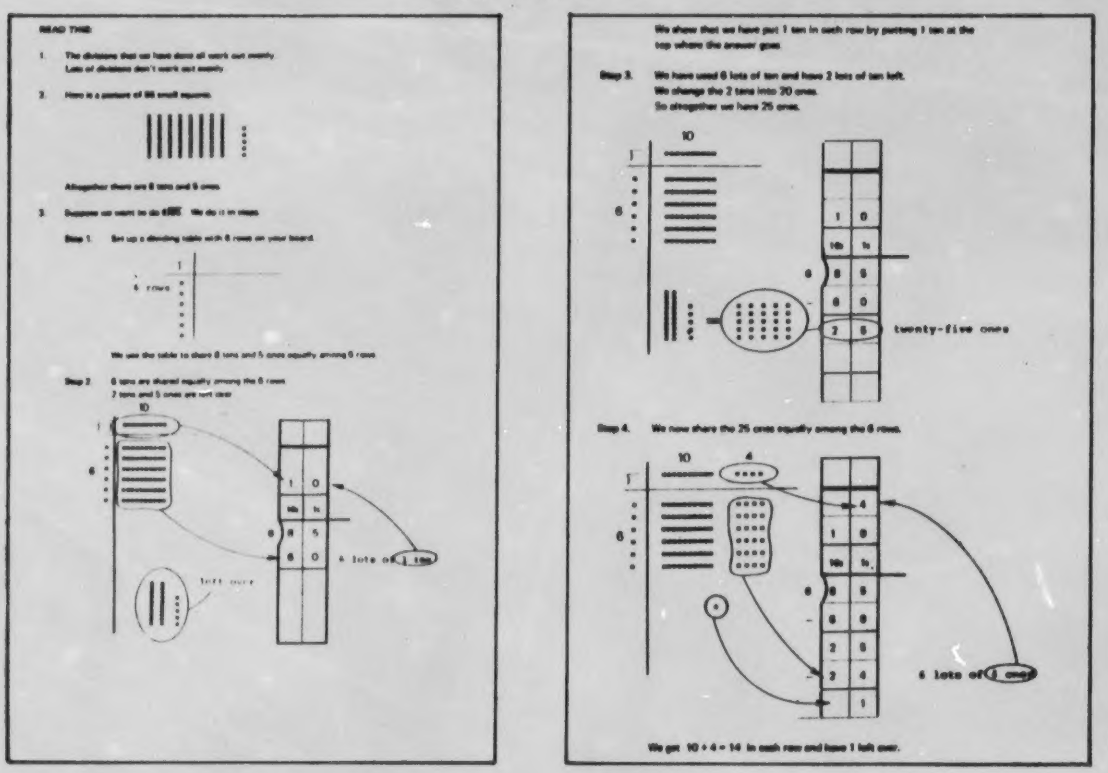
2. We put boxes around the pictures of 3 x 5, 3 x 10, 10 x 5 and 10 x 10 to help us count the small squares (units).
Altogether there are 15 + 30 + 50 + 100 = 195 small squares.
We write the multiplication in a place-value table.

15
X
13
100s
10s
1s
1 5
x 1 3
1 5
3 0
5 0
1 0 0
1 9 5
←3 lots of 5 ones
←3 lots of 1 ten
←10 lots of 5 ones
←10 lots of 1 ten
←13 lots of 15

3. So 13 lots of 15 = 13 x 15
= 195

Figure 12

Division Algorithm



READ THIS

1. The divisions that we have done all work out evenly.
Lots of divisions don't work out evenly.

2. Here is a picture of 85 small squares.

Altogether there are 8 tens and 5 ones.

3. Suppose we want to do $6\overline{)85}$. We do it in steps.

Step 1. Set up a dividing table with 6 rows on your board.

We use the table to share 8 tens and 5 ones equally among 6 rows.

Step 2. 6 tens are shared equally among the 6 rows.
2 tens and 5 ones are left over.

10
1
6
1 0
10s
1s
6
8 5
6 0
6 lots of 1 ten
left over

We show that we have put 1 ten in each row by putting 1 ten at the top where the answer goes.

Step 3. We have used 6 lots of ten and have 2 lots of ten left.
We change the 2 tens into 20 ones.
So altogether we have 25 ones.

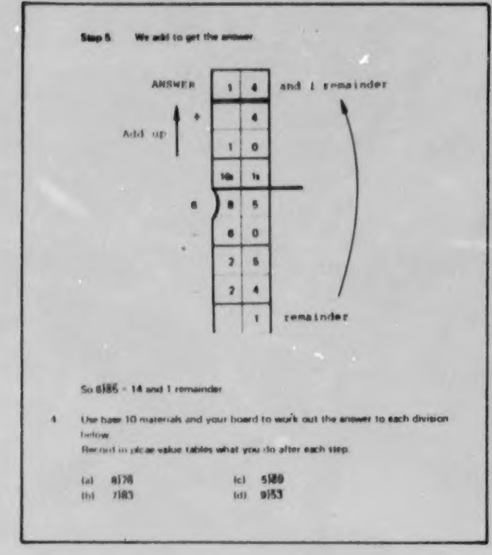
10
1
6
1 0
10s
1s
6
8 5
6 0
2 5
twenty-five ones

Step 4. We now share the 25 ones equally among the 6 rows.

10
4
1
6
4
1 0
10s
1s
6
8 5
6 0
2 5
2 4
1
6 lots of 4 ones

We get 10 + 4 = 14 in each row and have 1 left over.

Figure 12 (continued).



Step 5 We add to get the answer

ANSWER
1 4
and 1 remainder
Add up
+
4
1 0
10s 1s
6
8 5
8 0
2 5
2 4
1
remainder

So 6)85 = 14 and 1 remainder

4 Use base 10 materials and your board to work out the answer to each division below
Record in place value tables what you do after each step

(a) 8)78 (c) 5)89
(b) 7)83 (d) 9)53

Measurement concepts are developed using a similar sequence. First students compare and order measures. Later objects are measured using locally derived units of measure. Finally metric units are introduced as a standard system of measurement, necessary to aid communication between groups of people. Comparison activities are used with younger children to help develop measurement concepts (length, area, mass, etc.) and the language of measurement (long, distance, heavy, hot, etc.). As more accuracy is required, traditional units of measure are introduced and extended as necessary. Finally standardized (Standard International Metric System) units are introduced as an effective means of communication with people world-wide.

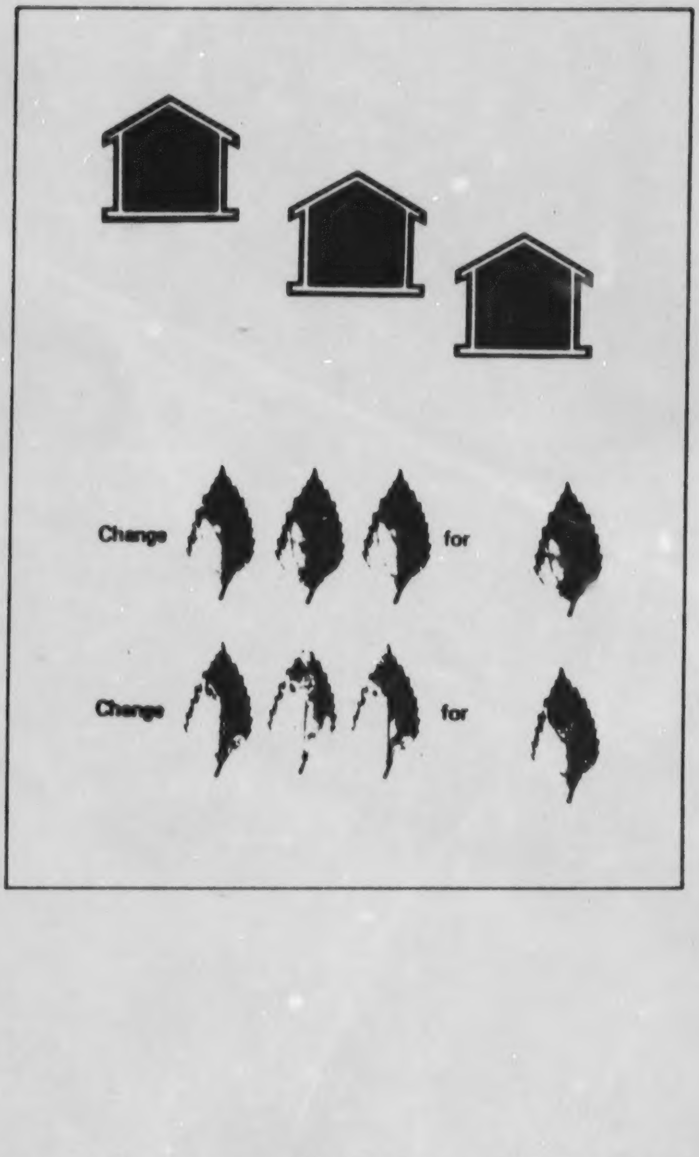
Classification concepts are developed in a similar manner – first solving problems with concrete objects (leaves, shells, stones, Kina Cards), then using only pictures of the objects and finally classifying words and numbers. Various relational concepts are developed (likeness, difference, smaller, one-more, etc.) as a means for developing the technical language necessary for mathematics learning. Early classificational and relational work seems as essential to such development in Papua New Guinea as elsewhere.

Student Activity Book: A student workbook consisting of an activity sheet for each lesson was developed for each grade level and distributed in sufficient quantities to ensure each student had a copy. The activity sheets were designed to follow-up a teacher demonstration. In many cases the exercises were worked in conjunction with a learning aid or an activity.

For example in grade two the idea of place-value is introduced through exchanging leaves. By rolling a die, children took turns picking up leaves and exchanging them according to a 3 to 1 exchange rule. The game ends when someone earns a yellow leaf. The activity sheet below was included in the student workbook and was to be used as a gameboard by pairs of children.

Figure 13

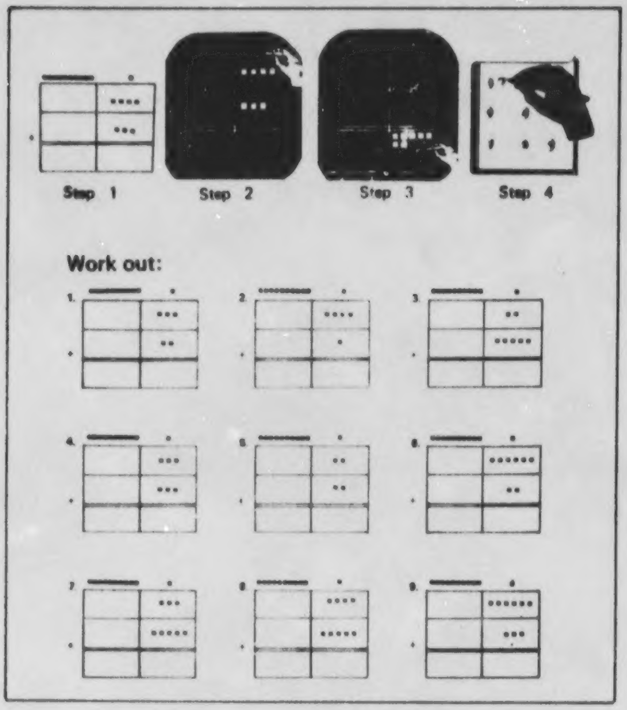
Grade Two Exchange Game



Based on our observations of the ralatively limited English language ability in grade two, we made every effort to minimize the language load on the activity sheets. This placed an additional burden on the teacher's ability to introduce each lesson and evaluate student performance. For example, when addition was introduced in lesson 591–1, the teacher was required to demonstrate several examples on the board prior to having the children work out the exercises independently.

Figure 14

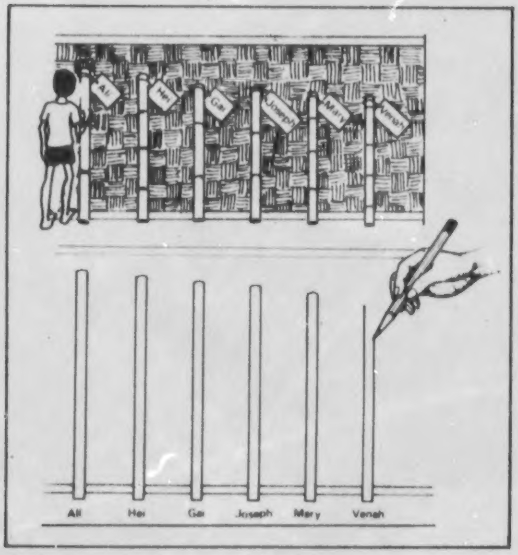
Introducing Addition


Step 1
Step 2
Step 3
Step 4
Work out:
1.
2.
3.
4.
5.
6.
7.
8.
9.

Whether the teacher could coordinate all the lesson elements (demonstration, materials management, small group activity, evaluation) would certainly be tested in complex lessons of this type. Other lessons required the teacher to organize large and small group activities where students would collect data and organize results.

Figure 15

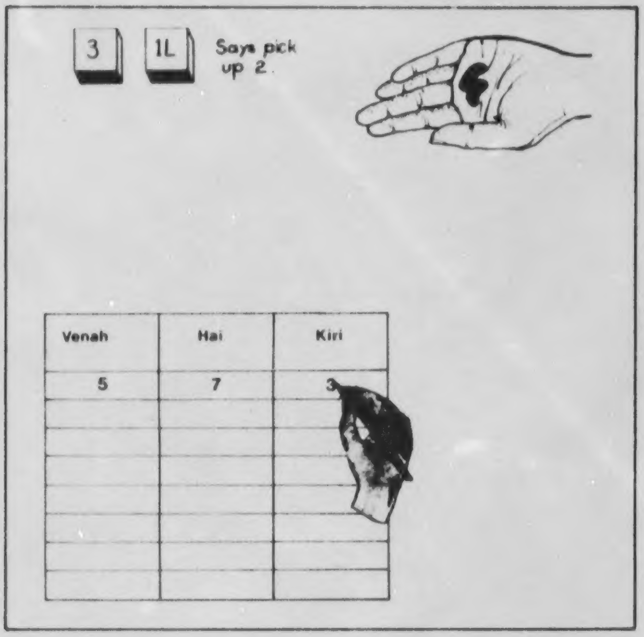
Ordering Length


Ali
Hei
Gai
Joseph
Mary
Venah

Several games were included to motivate the practice of number and operation skills.

Figure 16

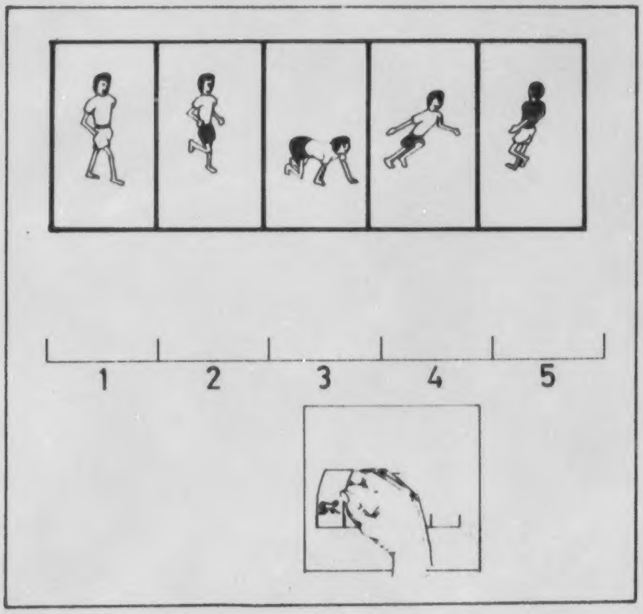
Counting Game


3
1L
Says pick up 2.
Venah
Hai
Kiri
5
7
3

Others required the children to trace pictures from the activity sheet and order them. For example, in lesson 55A the students were supposed to trace the racing figures and put them in the order in which they would finish.

Figure 17

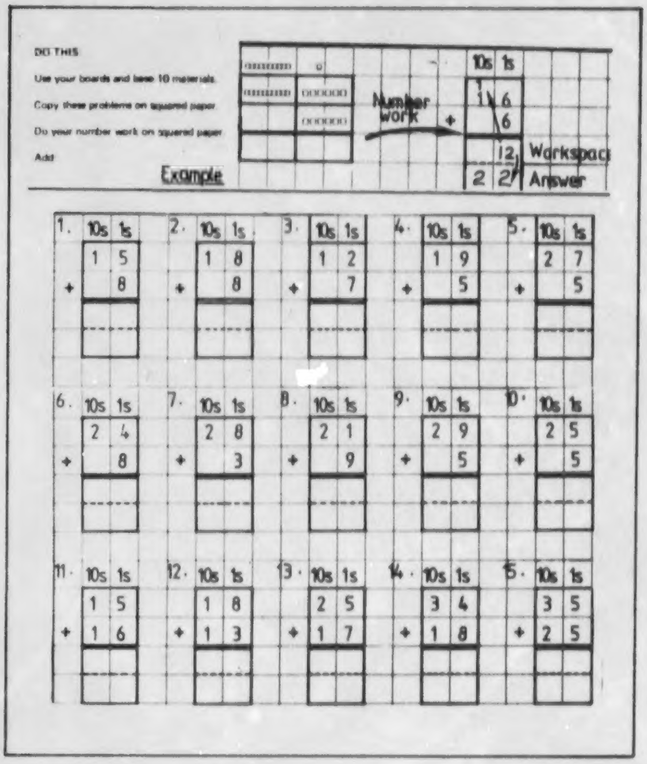
Ordering Time



In grade four the sheets were more self-explanatory. More instructions were presented directly to the students. Some lessons simply provided practice exercise for skills that had been developed in previous lessons.

Figure 18

Addition In Place-Value Tables



DO THIS

Use your boards and base 10 materials.

Copy these problems on squared paper.

Do your number work on squared paper.

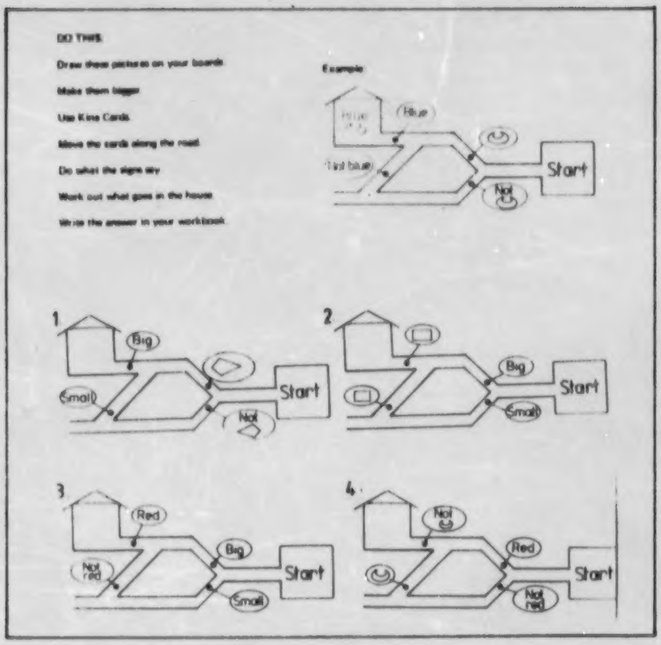
Add

Example
Number work
10s 1s
1 6
+ 6
12 Workspac
2 2 Answer
1. 10s 1s 1 5 + 8
2. 10s 1s 1 8 + 8
3. 10s 1s 1 2 + 7
4. 10s 1s 1 9 + 5
5. 10s 1s 2 7 + 5
6. 10s 1s 2 4 + 8
7. 10s 1s 2 8 + 3
8. 10s 1s 2 1 + 9
9. 10s 1s 2 9 + 5
10. 10s 1s 2 5 + 5
11. 10s 1s 1 5 + 1 6
12. 10s 1s 1 8 + 1 3
13. 10s 1s 2 5 + 1 7
14. 10s 1s 3 4 + 1 8
15. 10s 1s 3 5 + 2 5

Others provided examples and exercises to be carried out using learning aids. Activity 145C directed students to sketch a "road system" on their lap boards or on the floor. The objective was to follow the directions offered by the signs and see which Kina Cards end up in the house. This road system models conjunction (both kina and blue).

Figure 19

Classification Using Roadways



DO THIS

Draw these pictures on your boards

Make them bigger

Use Kina Cards

Move the cards along the road

Do what the signs say

Work out what goes in the house

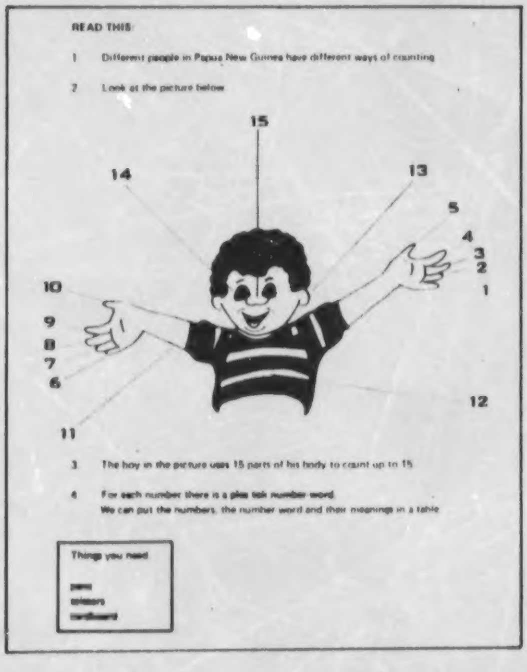
Write the answer in your workbook

Example
Blue
Not blue
Not
Start
1
Big
Small
Not
Start
2
Big
Small
Start
3
Red
Not red
Big
Small
Start
4
Not
Red
Not red
Start

In contrast to the grade two and four collections of activity sheets, grade six materials are organized as a textbook. The content is more fully developed within the text itself requiring less teacher input. The language load is greater as well. Indigenous counting systems are used as a starting point to discuss numeration systems, in particular base-10 place-value.

Figure 20

Body Counting System



READ THIS

1 Different people in Papua New Guinea have different ways of counting

2 Look at the picture below

15
14
13
5
4
3
2
1
10
9
8
7
6
11
12

3 The boy in the picture uses 15 parts of his body to count up to 15

4 For each number there is a ples tok number word
We can put the numbers, the number word and their meanings in a table

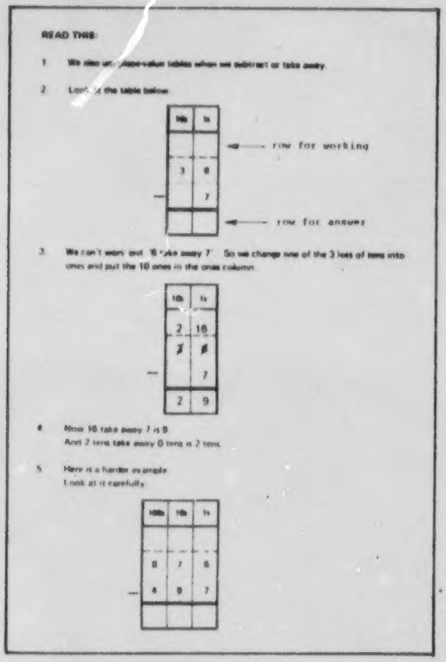
Things you need

pens
scissors
cardboard

Whole number operations develop from this point and continually relate back to the concept of place-value throughout the presentation. Concrete base-10 materials are used primarily for introducing each operation only. Pictures, squared paper exercises and drill games are used extensively.

Figure 21

Subtraction Using Place-Value Tables



READ THIS:

1 We also use place-value tables when we subtract or take away.

2 Look at the table below.

3 We can't work out '6 take away 7'. So we change one of the 3 lots of tens into ones and put the 10 ones in the ones column.

4 Now 16 take away 7 is 9.
And 2 tens take away 0 tens is 2 tens.

5 Here is a harder example.
Look at it carefully.

10s
1s
3
6
−
7
row for working
row for answer
10s
1s
2
16
~~3~~
~~6~~
−
7
2
9
100s
10s
1s
8
7
6
−
4
9
7

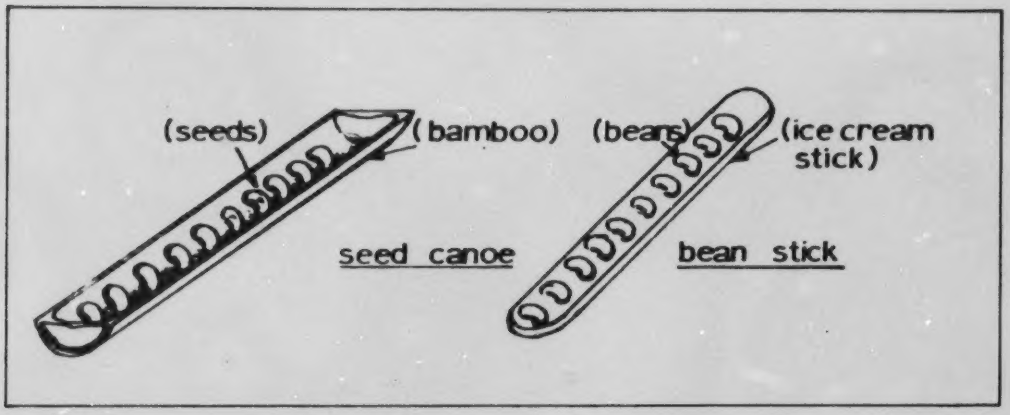
Teacher's Notes: A frequently expressed complaint by teachers and supervisory staff is that the teacher's guides for the current course of study (MACS) were insufficient to adequately support lesson programming in the field. Though no printed guide is sufficient in itself without adequate inservice support, we endeavoured to prepare a more detailed set of instructions for the teacher in the form of "Teacher's Notes" (1980).

Lesson aim and sequential instructions were provided for each activity, along with graphic examples of worked exercises and a materials list. Additional worked examples were included for more complex procedures (eg. concrete representation of multiplication and division). A copy of each student activity sheet with answers was included as well. No background content or methodological notes were included since basic issues of this type were covered during the two week inservice course and in IMP Working Paper Number 1, "Learning to Compute", (1980). The grade six teachers were provided with a copy of the student text. Since the content was more fully developed in the text itself, it was decided, in light of production time constraints, not to prepare a separate teachers' guide but to include the materials list and lesson aim in the student books. No answers were provided. Each site received two copies of the Teacher's Notes for each grade level and the observer had an extra copy as well. These, along with other materials, were delivered by the classroom observers when they arrived at the site in June 1980.

Base-10 Materials: Several different types of base-10 materials were considered for trialling. Locally produced wood blocks were discounted due to difficulty in producing accurate unit cubes as well as excessive shipping costs. Teacher/student constructed "seed-canoes" or "bean-sticks" were considered as well.

Figure 22

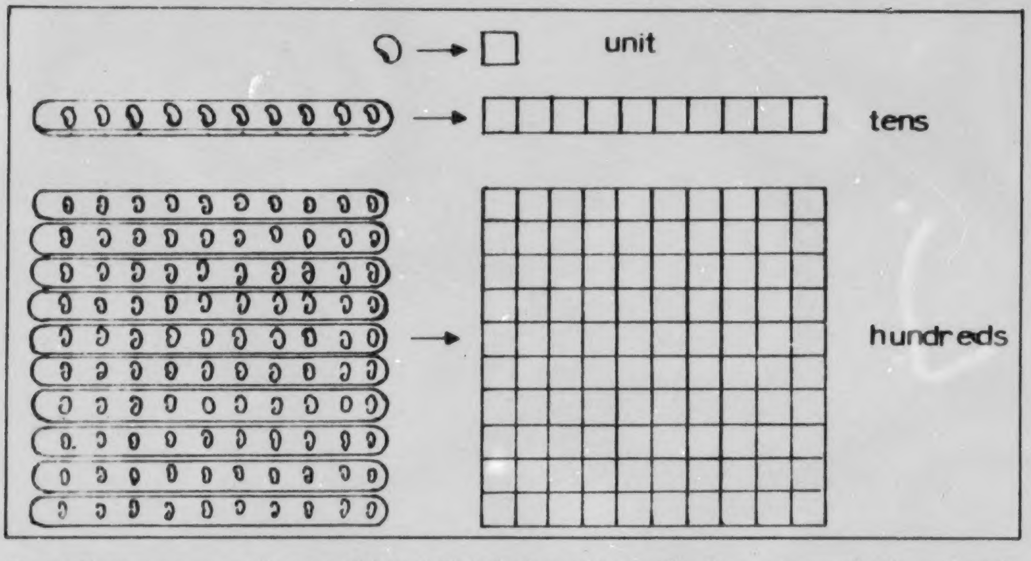
Seed Canoes



Putting ten canoes (or bean-sticks) together into a raft by gluing two sticks along the back gives a model for the 100's place. Separate seeds or beans are used as the unit.

Figure 23

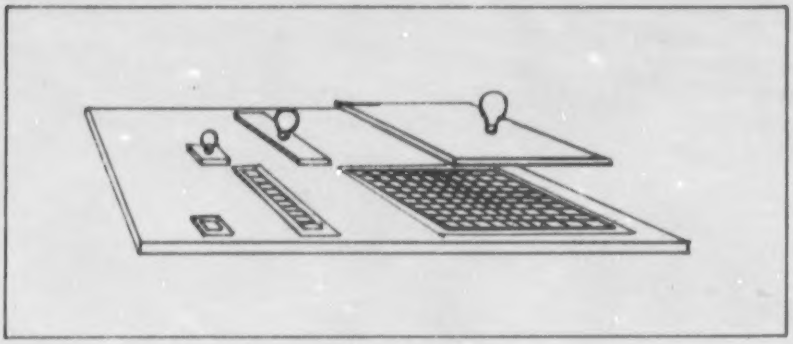
Base-10 Materials



Base-10 stamps were also considered. Teachers could use the three stamps (unit, ten and hundred) to make the necessary square centimetre designs on old cardboard boxes, cut them out with a razor blade and put them in envelopes ready for classroom use.

Figure 24

Base-10 Stamps



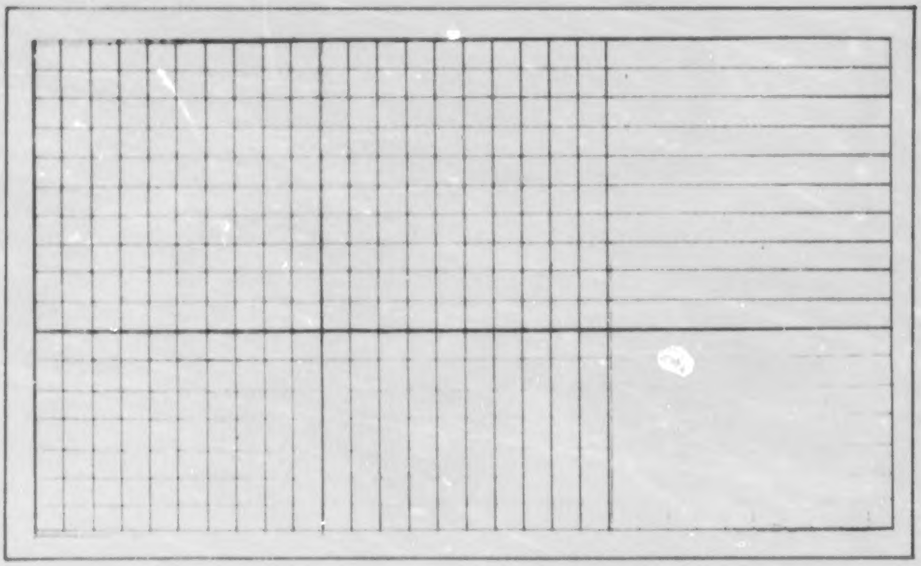
The set of three stamps cost K50 to produce commercially in Port Moresby. The technology exists to mass produce stamps at the Education Material Development Centre but initial capital outlay would be high and the photographic process has not yet been tried in Papua New Guinea. It is possible that ordering large quantities of stamps (7500) could reduce the cost sharply. However when ink pads are included the cost could well exceed that of alternative methods. Stamps have the added deficit of requiring teachers to construct the materials in the field – not a small task. Because of the already heavy commitment on teachers' and class time by other project and teaching requirements, it was decided that centrally prepared base-10 materials should be provided.

The final design involved punching the necessary "units", "ten-rods" and "hundred-rafts" out of heavy card using a machine die. The die pattern was constructed of high quality steel knives slotted into a plywood backing. Several different dies of this type (coins, tangrams) were constructed by Peter Thomas Pty. Ltd., Brisbane, Australia, at a cost of K50 to K100 each. Cardboard blanks were screen-printed with the necessary square centimetre markings.

The blanks were carefully placed against the pressure plate of a specially adapted obsolete letter-press (printing press) to which the die was attached. Cards were positioned and cut one at a time. Two passes were required to complete the process, one for the horizontal lines and one for the vertical lines. (All the knives could not be included in one die since the total knife length exceeded the capacity of the old press.) Total production time for 800 sets of cards was 27 hours (screen printing – 7 hours; die-cutting – 20 hours). Cost of materials and labour was approximately 6 toea per unit. Screenprinting cost could be reduced by purchasing coloured card instead of screening coloured background on white card. On large runs the slightly increased material costs should be more than compensated for by reduced wastage and labour expenses. Also a

Figure 25

Die-Cut Base-10 Materials



larger press, designed for such die-cutting tasks, could reduce the cutting process to one step. A single die could be fabricated affording a more accurate product and at the same time reducing wastage. Creasing knives could be incorporated into such a die to stamp in the centimetre markings thereby eliminating the need for screen printing altogether. This would increase the knife length considerably and would require a three tonne press (approximately K3000) to ensure an accurate job.

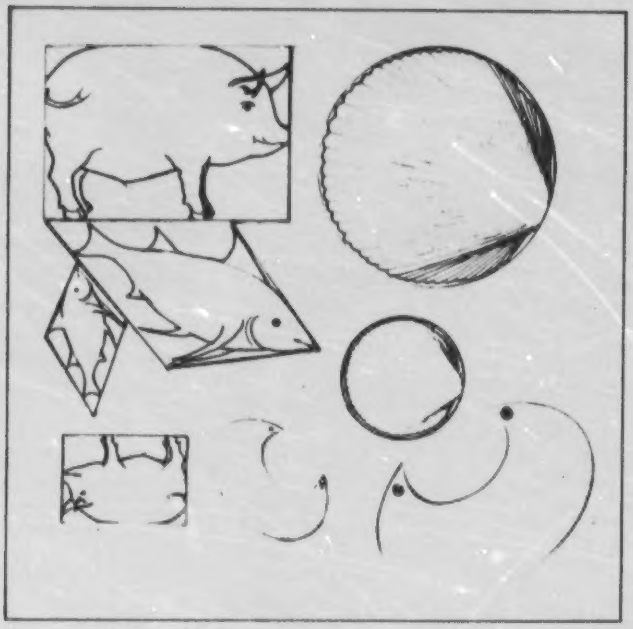
Each child received a set (70 units, 24 tens and 2 hundreds). The teachers quickly separated the die-cut cards with ordinary scissors, put each set in an envelope provided and labled them. Fifty sets were provided to each school. The die-cutting process has far-reaching potential for producing professional quality, yet extremely inexpensive, learning aids for all subject areas.

Kina Cards: Structured attribute blocks are incorporated into the current MACS lessons. Most schools do not have access to these materials. Though local materials (shells, leaves) are sometimes substituted by innovative teachers, this rarely seems to be the case. Kundu Cards, which can be produced by the teacher, are also recommended in the MACS guides. They consist of a set of 24 cards displaying pictures which can be classified by three attributes [size (2), shape (4), colours (3)]. Though Kundu Cards have the obvious advantage of being teacher produced, they lack the perceptual impact we feel is necessary for use by young children learning to logically classify.

A set of 32 cards consisting of four shapes, four colours and two sizes were designed. Each shape was chosen to represent a common item in the child's environment (pig, kina, shell, fish). Kina Cards provide a more limited set of attributes (no thickness attribute) than previously used attribute blocks, but one more colour than the Kundu Cards. They are inexpensive (die-cut cardboard), colourful and durable. A complete set of 32 cards costs about 12 toea. Below is a set of eight Kina Cards. Each set was produced in four colours (red, yellow, green, blue), and forty sets were sent to each site.

Figure 26

Kina Cards



Coins: Play money was used as an aid during place-value and number operation development as well as a medium for practice in making change. One-toea and two-toea coins were screened and die-cut on brown card. Five-, ten- and twenty-toea and one-kina coins were die-cut from silver card. One set of cards cost 8 toea to produce. Forty sets were sent to each school.

Figure 27

Die-Cut Coins (1)

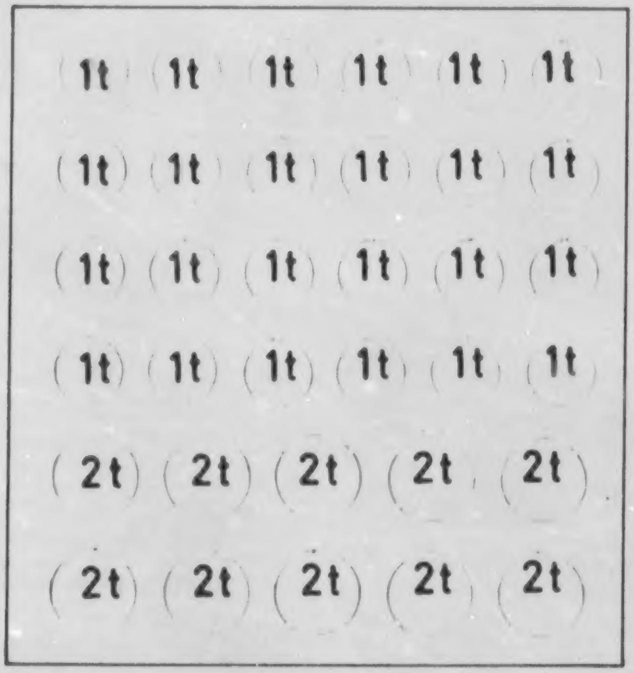
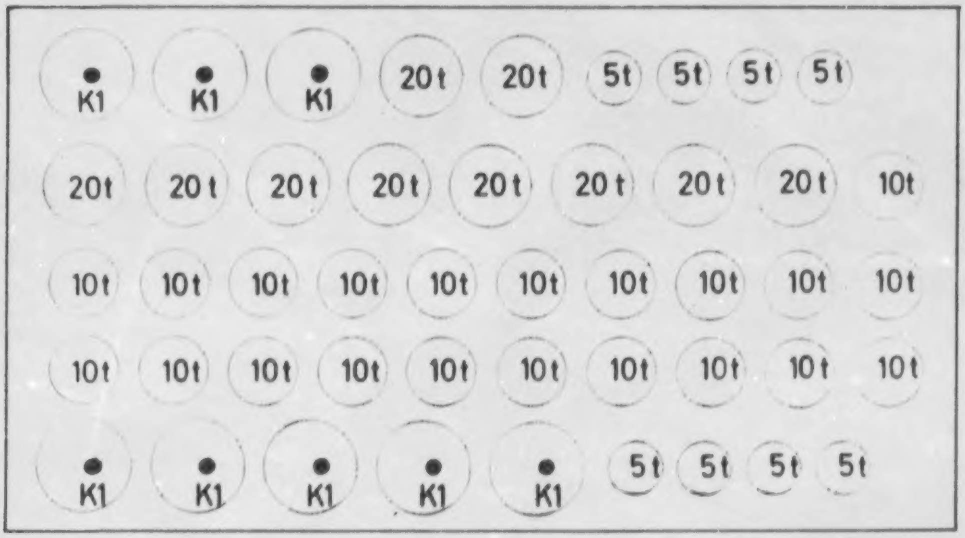

1t 1t 1t 1t 1t 1t
1t 1t 1t 1t 1t 1t
1t 1t 1t 1t 1t 1t
1t 1t 1t 1t 1t 1t
2t 2t 2t 2t 2t
2t 2t 2t 2t 2t

Figure 28

Die-Cut Coins (2)

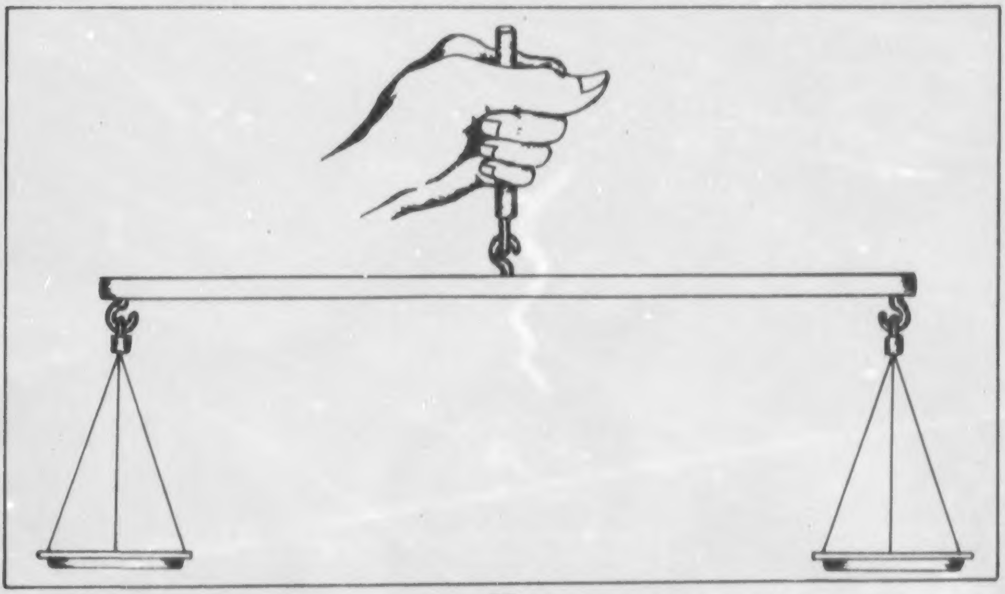

K1
K1
K1
20t
20t
5t
5t
5t
5t
20t
20t
20t
20t
20t
20t
20t
20t
10t
10t
10t
10t
10t
10t
10t
10t
10t
10t
10t
10t
10t
10t
10t
10t
10t
10t
10t
10t
10t
K1
K1
K1
K1
K1
5t
5t
5t
5t

Wooden Cubes: Twenty wooden cubes five centimetres on an edge were supplied to each school. They were coated with chalkboard paint. We decided on the rather large size so that when used as dice they wouldn't fall through cracks in bush material tables and floors. Several games called for dice. Various numbers and letters can be easily written on the faces of the cubes using chalk.

Pan Balances with Mass Pieces: Five hand held pan balances were supplied to each school with an assortment of mass pieces (1 gram centicubes, 20g x 2, 50g x 2, 100g, 200g, 500g, 1000g). The balance was designed to be simple yet accurate to 10 grams. Two paint-can covers serve as pans. They are attached to the plywood cross-member with small chains. The apparatus is suspended from a small wooden handle which can be attached to an overhead beam or table using strong string.

Figure 29

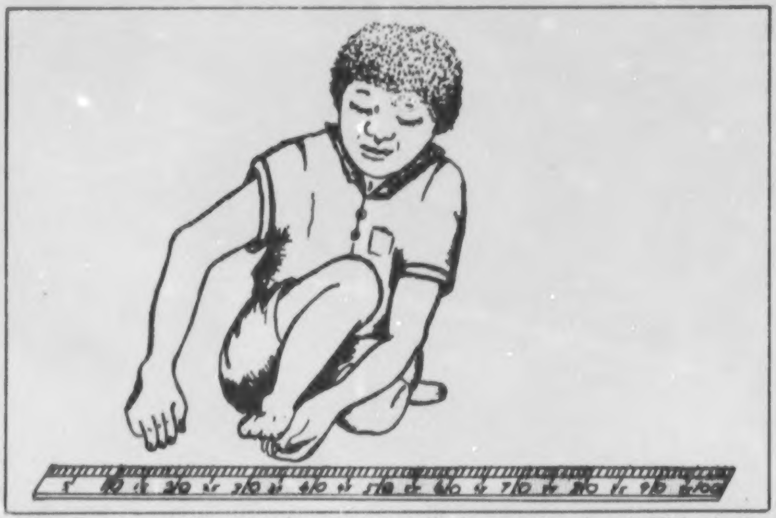
Pan Balance



Metre Stick: Eight plywood metre sticks marked off in centimetres were supplied to each school. Decimetres are alternately painted green along the length of the stick. The metre stick is intended for use as a standard for student produced metre sticks made from local materials.

Figure 30

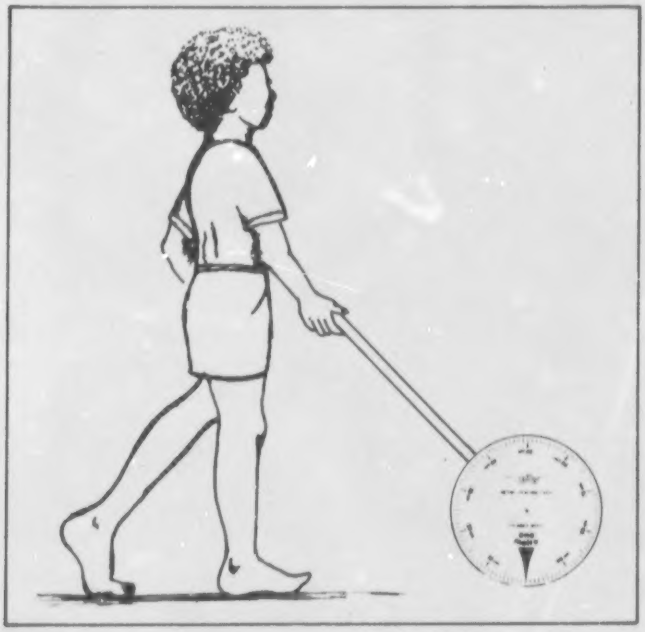
Metre Stick



Trundle Wheel: Four trundle wheels were supplied to each school. This device is useful for measuring long distances. A plywood disc, one metre in circumference, is attached to a supporting handle by passing a bolt through its centre. A small piece of plastic cut from a juice container is attached to the handle so that it clicks every time a nail embedded in the disc passes. By rolling the wheel along the ground one can accurately measure long distances by simply counting the clicks. Each click represents one turn of the wheel along the ground — one metre.

Figure 31

Trundle Wheel



Squared Paper: Paper printed with a one centimetre square grid (17 x 26) was used by the students to help them keep their columns lined up when completing number operation exercises (+, –, x, ÷). The paper was also used for making graphs, multiplication tables and other aids. A booklet of thirty sheets was supplied for each student.

ASSESSMENT INSTRUMENTATION

Four categories of data were collected during the course of the study.

1. A diversified set of field-notes were compiled by trained classroom observers over the six week implementation period.

2. Eight cognitive measures were administered to a stratified random sample of 15 children at each grade level.

3. Pre-, post- and retention achievement tests for mathematics and language were administered to all the subjects.

4. Several measures of teacher competence were administered and an evaluation was completed by each participant.

In the following sections each instrument will be described in detail ending with a brief description of the classroom observers involved in the study.

Field-Notes: A guide to preparing field-notes (Levin, Gearhart, Souviney, 1980) was developed in order to standardize procedures and enhance the comparability of the information gathered. The guidelines were compiled and field tested in Port Moresby in the weeks prior to the implementation period. Severe time constraints limited the amount of field testing possible. Some observers found it necessary to adapt procedures to unique field conditions, especially with regard to documenting language-use and classroom interaction variables. On the whole the lesson implementation data was reasonably comparable across sites.

Events during each lesson were documented according to a consistant three step procedure:

1. Preliminary Interview
2. Classroom Activity Record
3. Debriefing Interview

Preliminary Interview: First the teacher was interviewed about the upcoming lesson. The interview consisted of eliciting questions from the teacher regarding any forseen problems with the lesson and possible solutions. An evaluation of the usefulness of the Teacher's Notes was made, along with suggestions for improvement. A narrative record was made during the interview. The observer wrote summary comments after the interview detailing their reaction to the discussion and provided a cumulative analysis of the teachers understanding of the curriculum materials. The interview continued with a discussion of the lesson for the other grade levels.

Classroom Activity Record: The second step in the field-note process was designed to document the classroom events associated with lesson implementation. The four types of Classroom Activity Records are listed here.

1. Curriculum Implementation
2. Language-Use
3. Classroom Interaction
4. Student Interviews

Each lesson was designated for documentation using one of the four categories above. A few lessons were designated "optional" and it was left to the observer to determine how these were to be documented. A brief curriculum implementation summary was prepared for all lessons regardless of whether they were designated Curriculum Implementation, Language-Use, Classroom Interaction, Student Interview or Optional.

Curriculum Implementation: Before the lesson any changes in classroom configuration was noted, who was present and absent and the transition into the lesson. When the lesson began a factual and descriptive record of the ongoing narrative was kept in real time. Note was made of any changes in procedures from those expressed by the teacher during the pre-interview. We were particularly interested in the basis on which the teachers decided to move from one lesson element to another. Any effort on the part of the teacher to evaluate student understanding prior to moving on in a sequence of lesson events was noted. After the lesson the observer immediately wrote a summary of key lesson elements (ie. use of materials, problems with content, pertinent student responses to evaluation queries. Reflective, cumulative observer comments were included here as well. Only this Summary and Comment section was included for those lessons not designated as Curriculum Implementation.

Language Use: A special form was developed to assist with collecting data on the context in which English, Pidgin and **tok ples** were used in the classroom. A coding scheme was developed to document the following variables:

1. Classroom Organization (Whole class, small group, pairs, individuals)

2. Lesson Phase (Introduction, activity, closing discussion)

3. Narrative (Additional description of events)

4. Time (Marks language shifts)

5. Language (English, Pidgin, **tok ples**)

6. Speaker (Teacher, Class, Group, Pair, Individual)

7. Addressee (Teacher, Class, Group, Pair, Individual)

8. Interactional Function (Question style and response)

9. Lesson Function (Lesson talk, organizational talk, irrelevant talk)

At the start of the lesson the first frame (row) on the form was coded for each variable. A new frame was coded each time the students or teacher shifted to a new language. Audio tapes were made by some observers and were used to complete the frames if they were unable to maintain accurate coding in real time.

Classroom Interaction: Approximately one lesson per week per grade level was audio-taped and simultaneously coded for type of speech events and evaluation procedure. Pilot audiotapes were made before the first scheduled Classroom Interaction lesson to determine optimal record placement in the classroom.

A rough transcript was prepared subsequent to the lesson. The teacher was used at some sites to help identify the speaker, addressee and a few initial words of each speaker's turn. Essential nonverbal and off-tape narrative that described non-audible events was documented in real time in the narrative column to help interpret the talk later. The tapes are currently undergoing transcription at the University of California, San Diego, and Virginia Commonwealth University. Results of the planned discourse analysis will be reported at a later time.

The following structure was developed to assist in coding classroom talk. A specially developed coding form was used to standardize the collection format.

A. Teacher structures interaction.

    1. Open invitation to bid (teacher addresses whole class).

        Student Response Type:
        a) Chorus (more than one spontaneous respondent)
        b) Callout (one spontaneous respondent)
        c) Teacher selects (individual or sub-group)

    2. Individual nomination (Teacher addresses one student).

B. Student structures interaction (asks question).

    Teacher Response Type:
    1. Answers question
    2. Ignores question

C Teacher initiated evaluation.

    1. Positive evaluation
    2. Negative evaluation
    3. Teacher redirects evaluation to student(s)

At the end of the class period, **Summary and Comments** were written. Patterns of student participation and turn-taking procedures are summarized as well as any expressed formulation of turn-taking rules and prohibitions by the teacher (ie. "Everybody is supposed to raise their hands". "Don't call out". "Everyone answer together".)

The teachers' procedures for structuring small group interaction and evaluation are summarized as well. For example:

1. Did the teacher select a leader or ask the students to select a leader?

2. Were the students supposed to work out a plan on their own?

3. How did the students organize subsequent interactions?

4. Did the students call to the teacher for help?

5. Did the teacher supervise?

6. Did the teacher note errors in order to diagnose childrens' understanding?

7. Did the teacher note errors and then work with the child to help with any misunderstanding concepts, tasks and algorithms?

8. Did the teacher ask children about processes and procedures (ie. "How did you . . . ?" "Why is . . . ?" "What if . . . ?" questions) that require reflection and analysis.

Subsequent to the objective summary, subjective comments were made on changes observed over time, differences across grade levels and other general impressions.

Student Interviews: Interviews with students from each class were conducted after selected lessons (approximately one per week per class). The teacher was asked to suggest high and low achieving students who would be responsive in a clinical interview setting. Papua New Guinea children seem to be generally quiet in situations like these, so we attempted to select children who seemed comfortable and expressed interest in talking about their maths work. A local translator was used in some cases with younger children.

The child was asked to describe what went on in the lesson. Interviewers were cautioned not to ask leading questions. We sought to probe the child's understanding of the specific activity and the underlying concepts to see if the child could coordinate the current lesson with previous knowledge and skills. The child was asked to demonstrate the specific skill or procedure developed during the lesson.

Debriefing Interview: The third step in the organization of the field-notes was the Debriefing Interview. After each lesson the teacher was queried regarding how the lesson went from his point of view. This debriefing normally occurred in the evening, just before the preliminary interview for the next day's lesson. The interview generally followed the line of questioning below:

1. How do you think the lesson went?

2. Did anything unexpected happen?

3. Did you make any changes during the course of the lesson?

4. Would you do the lesson differently next time?

5. Do you think that the students understood the lesson? How do you know?

6. Are there modifications that can be made in the lesson or in the instructions that would help other teachers implement this lesson?

In summary the field-notes for each day contained:

A Preliminary Interview

1. Teacher Questions and Comments
2. Narrative
3. Comments

B Classroom Activity Record (one of the following categories for each lesson)

1. Curriculum Implementation
    a) Detailed Field-Notes
    b) Summary Field-Notes (included with Language-Use, Classroom Interaction, Student Interview or Optional lessons as well)
2. Language-Use
3. Classroom Interaction
4. Student Interview

C Debriefing Interview

School and Community Setting: In addition to the field-notes documenting daily classroom events, an abbreviated ethnography was compiled. The ethnography detailed the history of schooling in the area and the cultural/social makeup of the surrounding community. The data was compiled over several weeks and involved interviewing various school and community members as well as personal observation.

Information gathered on the **School Setting** included:

1. Maps of the school, classrooms and surroundings.
2. School construction specifications.
3. History of schooling in the area.
4. Materials and resources currently available at the site.
5. Teacher's professional background.
6. School schedule and evaluation procedures.
7. Student questionnaire and essay (life in school and in the village, career expectations, language preferences, etc. – grade six only).

The **Community Ethnography** was limited in general to brief descriptions of the following cultural/social categories.

1. Social geography of school catchment area.
2. Political structure and economic activities.
3. Religion.
4. History of social/economic contact outside the area.
5. Language use in the community.
6. Education and socialization patterns outside the classroom.
7. Family/clan organization.

Cognitive Assessment: Seven cognitive tasks were selected from an initial battery of nine. Two tasks (Single Seriation and Coding) were eliminated during trialling due to lack of variance across grade levels. A conservation of length task was added, making a total of eight measures. The tasks were selected to sample a range of levels of cognitive processing – low level memory behaviours, various conservation tasks and classification experiments requiring a more sophisticated use of language.

Cognitive Tasks

1. Visual Memory (objects)
2. Visual Memory (symbols)
3. Memory Space
4. Conservation of Number
5. Conservation of Length
6. Double Seriation
7. Logical Classification
8. Class Inclusion

Each task was trialled at the five sites. The original task protocols were adapted to accommodate unanticipated procedural or language problems. The classroom observers administrated the tasks prior to the classroom observation period. Each subject was interviewed in a one-to-one clinical setting. With the aid of a local translator the talk-back technique was used to finalize the appropriate language procedures. Interviews in general were conducted in the local vernacular or Pidgin for grade two children. With older children interviews were in English with Pidgin and **tok ples** used as necessary. Though the children seemed to view these tasks as somewhat bizarre as compared to problems they normally encountered in school and in the village, we consider the results reasonably robust due to the extensive use of unscored training tasks associated with each experiment.

Detailed administration procedures were prepared for each task to help standardize interview protocols. A standard record form was used for all interviews. The materials used are listed below.

1. Visual Memory (objects)
    a) Array board (3 x 4)
    b) Twelve small objects (coin, seed, leaf, pebble, key, shell, stick, peanut, match, pencil, chalk and bamboo section)

2. Visual Memory (symbols)
    a) Array board (3 x 4)
    b) Number cards (1 – 12)

3. Memory Space
    a) Mr. Kiri test-books

4. Conservation of Number
    a) Twenty 1-toea coins

5. Conservation of Length
    a) Two equal pieces of pitpit or bamboo (locally collected)

6. Seriation (double)
    a) Array board (3 x 3)
    b) Set of nine proportioned rods (three lengths, three thicknesses)

7. Logical Classification
    a) Four pre-training sticks (blue and red)
    b) Eight sorting cards (birds-of-Paradise and arrows – two sizes, two colours)

8. **Class Inclusion**
    a) Eight pig tusks or dog teeth
    b) Four arm-bands

Instructions for administration were as follows:

Visual Memory (VM1 – objects; VM2 – symbols): The interviewer presents the child with a 40 cm x 30 cm board containing three rows of four, 10 cm x 10 cm cells. Two small objects are placed randomly in two cells (ie. seed and coin). Ask the child to *"Look at these things carefully. Remember where they go."*

After 10 seconds remove the objects and hand them to the child. Then say *"Put the things back where they were."* If the child is unsuccessful, repeat the task using the same objects in two different cells. After successfully replacing the two objects, repeat the task with six objects in a 2 x 3 array in the upper left-hand corner of the board (interviewers perspective) nearest the child.

Next place twelve objects (out of the subject's view behind a small screen) in the 3 x 4 array (A or B below). Say to the child, *"Look at these things carefully. Remember where they go."* After 45 seconds remove the objects, hand them to the child and say, *"Put all the things back in the right places."*

Allow as much time as necessary for the child to replace all 12 objects or until it is clear he is unable to go on. The maximum score is 12, one for each correct placement in the final task.

Repeat the task using 12 cards with the numbers 1 through 12 written on them arranged as C or D below. Do not repeat the pretraining exercise. Score in the same manner.

Pretraining

coin	key	shell
seed	top	rock

Objects – VM-1

A

match	coin	bamboo	seed
leaf	top	shell	pencil
key	stick	rock	peanut

B

top	chalk	stick	key
seed	leaf	shell	bamboo
match	rock	pencil	coin

Numbers – VM-2

C

10	3	12	5
9	7	1	11
2	6	8	4

D

3	11	9	1
2	7	10	5
8	6	4	12

Memory Space: Introduce the test booklet, consisting of 21 test items and three training items with one to seven body parts randomly coloured (adapted from Case, 1977). Each page is interleafed with a grid distractor page and an additional blank outline of Mr. Kiri.

Introduce the test as follows: *"This is Mr. Kiri. He is a tricky man. He will try to trick you by changing colours. Look here* (pointing to the left hand, which is coloured red)

Mr. Kiri has changed his hand. Now he is going to hide. (remove the practice item from view by turning to the next page [a distractor grid] in the test booklet.) *Now* (turn the page again and show a blank outline), *point to the part that was red."*

"Now look again. (present the second practice card with two body parts coloured in) *I'll keep Mr. Kiri here for 5 seconds. When he hides, you point to all the body parts that were coloured. Ready? Go."* (turn the page to the grid after 5 seconds, then turn to the outline page).

"Here is Mr. Kiri again (show the next practice page for 5 seconds, turn to the outline page). *Point to all the body parts that were coloured."*

Repeat the practice items if necessary to ensure the child understands the task. After the three practice items are completed, present the 21 test items by showing Mr. Kiri for 5 seconds. Turn the page to the grid then to the outline. The subject is not permitted to start pointing before the test item is removed (ie. he is not allowed to touch it). Other strategies which might serve as memory aids (such as closing one eye or clenching a hand) are also forbidden. Be careful not to skip any items (pages).

Subjects receive credit only for items which are recalled perfectly. Record only the test items which are recalled without error. Use the record form provided.

M-Space scores are computed by assessing the highest level (1–7 coloured parts) which the subject recalled perfectly on 3 out of 3 items. To this value add 0.33 for each item (page) recalled perfectly in the next highest level only. For example if a child recalled 3 out of 3 items at level 2 (2 coloured body parts) and recalled 2 out of 3 items at level 3, the M-Space score would be computed as follows:

M = 2 + 0.33 + 0.33 = 2.66

Table 13 describes the item composition for the Mr. Kiri Memory Space task.

Table 13

Mr. Kiri M-Space Task – Item Composition

Pretraining Items
A. L. Hand
B. R. Ear and L. Foot
C. R. Hand and Nose

Item	Level	1	2	3	4	5	6	7
1	2	Pants	L. Arm					
2	3	L. Foot	R. Arm	R. Eye				
3	5	L. Leg	Mouth	L. Ear	Hair	L. Hand		
4	4	R. Foot	Pants	Mouth	R. Hand			
5	6	R. Leg	Shirt	L. Ear	Nose	L. Eye	R. Hand	
6	1	R. Arm						
7	7	L. Foot	Pants	R. Arm	L. Ear	Nose	R. Eye	Hair
8	5	R. Foot	L. Leg	R. Arm	R. Eye	L. Ear		
9	2	R. Hand	Hair					
10	7	L. Leg	Shirt	L. Hand	L. Ear	L. Eye	Mouth	Hair
11	4	Pants	R. Eye	Hair	R. Hand			
12	3	R. Leg	Mouth	R. Ear				
13	1	R. Foot						
14	6	L. Foot	Pants	R. Arm	Mouth	Hair	L. Hand	
15	7	R. Foot	L. Leg	R. Arm	Nose	L. Eye	L. Ear	L. Hand
16	3	L. Leg	R. Eye	Hair				
17	1	R. Hand						
18	5	R. Leg	Shirt	R. Hand	L. Ear	Hair		
19	4	L. Leg	R. Arm	Mouth	R. Ear			
20	6	L. Foot	L. Art	L. Ear	R. Eye	Hair	R. Hand	
21	2	Nose	L. Ear					

Conservation of Number: Begin the pretraining task by presenting the child with two lots of 1-toea coins (3 on left, 10 on the right). Ask the child, *"Which pile has more coins?"* Put out 5 and 5. *"Which pile has more coins now?"* If one lot is chosen over the other try to compensate for the qualitative deficit (i.e. "This one is bent, lets replace it.") to encourage strictly quantitative comparisons.

Next the interviewer presents the child with two lines of seven coins each arranged in one-to-one correspondence. The child is asked, *"Do these two lines have the same number of coins?"* (point to both lines; wait for answer). *"Can you show me why they are the same?"*

If the child doesn't answer correctly, point out the one-to-one correspondence and repeat the activity. Once the child agrees that the lines have the same number of coins the interviewer spreads out **one** of the lines evenly so that the coins are no longer matched directly one-to-one. Then ask,

1. *"Do these two lines have the same number of coins now?"*
2. *"Can you show me why they are the same (one is more)?"*

Finally the interviewer moves the coins back into direct one-to-one correspondence and again asks,
"Do these two lines have the same number of coins now?"
"Can you show me why they are the same?"

Repeat the task using ten coins in each line. This time, however, spread out one line and collapse the other into a pile.

The maximum score is 4, **one** point for answering each of the two questions correctly on the seven **and** ten coins problem.

Conservation of Length: The interviewer presents two equal lengths of pitpit or bamboo. They are placed on the table parallel to the edge facing the child, approximately 10 cm apart with the ends collinear. The interviewer asks, *"Are these two pitpits the same length?"* If the child does not indicate equivalence, cut a bit off the "longer" one until equivalence is established.

Next translate one pitpit in a parallel manner approximately half-way along the other pitpit. Ask,

1. *"Are these pitpits the same length now or is one longer?"*
2. *"Can you show me why they are the same (one is longer)?"*

Finally return the pitpit to its original position and ask, *"Are these two pitpits the same length now or is one longer? Can you show me why?"*

The maximum score is 2, one point each for correctly answering questions 1 and 2 above.

Double Seriation: The interviewer presents the child with a 30 cm x 30 cm board divided into three rows of 10 cm x 10 cm cells. Nine wooden rods are used, three each with diameters of 1.5 cm, 2.5 cm, and 3.5 cm. Each set of three rods has heights 3 cm, 5 cm and 7 cm.

The interviewer places one rod on each of the nine squares with height descending from right to left and thickness descending from front to back (interviewers perspective). The

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tallest, thickest rod is in the right-hand corner (interviewers perspective) furthest from the child. Say *"See the way I put the rods."* Remove the three thin rods and ask the child to *"Put these rods back in the right places."* If the child fails ro replace them correctly, the interviewer replaces them. Repeat with the three tall rods.

When all the rods are in place again, remove all but the **tall, thick one.** Tell the child, *"Now you have put all the rods back in the right place."* The interviewer corrects any errors. Next remove **all** the rods and repeat.

The maximum score is 19, one point each correct row placement (1 + 1) and one point for each correct rod placement in the final two trials (8 + 9). If a child transposes two complete rows give half credit (3 points for two rows).

Logical Classification: The interviewer presents the child with pretraining materials consisting of two blue and two red sticks. One of each colour is 6 cm long and the other is 9 cm. The long blue stick and short red stick are sharpened on one end. The child is asked *"What is the colour of this stick?"* (pointing to a blue stick) *"And this one?"* (pointing to a red stick). If the child doesn't know the colour names the interviewer says, *"This stick is blue and this is red"* (pointing to the appropriate sticks).

The child is then asked, *"How can these sticks go together?"* If the child doesn't respond, the interviewer separates the blue from the red sticks and says, *"These two go together because they are the same colour. So do these"* (pointing to the appropriate sets).

The sticks are removed from the table and are handed to the child. The interviewer then says, *"Show me another way the sticks can go together."* Again if the child fails to respond the interviewer demonstrates that the sticks can be placed together according to size by moving the long sticks together and the short sticks together. The interviewer says, *"See, we can put the long ones together and the short ones together."* Follow the same procedure for the pointed and flat-end sticks.

Following this training period, four line drawings of birds-of-paradise and four line drawings of arrows are presented to the child. The drawings are displayed on 10 cm x 10 cm cards in two colours (blue and red) and two sizes (3 cm, 7 cm), one of each size and colour.

The interviewer says, *"We're going to play the same game with these cards. How can these cards go together?* (pause) *you must use all the cards."* If the subject responds by separating the cards into two piles according to shape (bird, arrow), size (large, small) or colour (red, blue), say *"Why did you put these here?"* (pointing to one pile) *"And here?"* (pointing to the other). Next say, *"Can you make new groups so the cards go together?"*

If the child does not complete an initial classification do not continue the task. Record any interesting functional or confounded classifications. Score 1 point for each completed classification. If the score is more than 3, provide detailed explanation.

Class Inclusion: The interviewer presents the child with eight pig-teeth (for MP use dog-teeth) and four arm-bands (all considered "bilas" – body decorations). The child is asked, *"What do you call these?"* (point to one pig-tooth) *"And these?"* (point to one arm-band). Work out the names in Pidgin or **tok ples** as necessary.

After the objects are identified as above, the interviewer says *"We call all of these things bilas. What do you call these bilas?"* (point to one group) *"What do you call these bilas?"* (point to other group). *"What do you call these things?"* (bilas).

Next the interviewer tells the child, *"Touch each tit bilong pik (pig-tooth)" "Touch each paspas (arm band)" "Touch each bilas (body decoration)".* The process is repeated if necessary until the interviewer is sure the child knows the names of each type and that they are all called bilas.

The child is then asked,
1. *"Are there more tit bilong pik, or more paspas?"*

After a response the interviewer asks,

2. *"Are there more tit bilong pik or more bilas?"*
3. *"Can you show me why?"*

The maximum score is 3, one point for answering each numbered question correctly.

ENGLISH	PIDGIN	TOK PLES
1. pig-teeth	1. tit bilong pik	1.
2. arm-band	2. paspas	2.
3. body decorations	3. bilas	3.

Achievement Instruments: Three types of achievement tests were administered to all subjects:

1. Primary Mathematics Achievement Test (PMAT)
2. Test of Arithmetic Skills (TAS)
3. Reading and Dictation (English)

The **Primary Mathematics Achievement Test** was developed expressly for use in the current project. It is a wide range criteria referenced instrument developed to measure achievement on selected objectives in the current MACS course. The following objective matrix was compiled from a review of the MACS syllabus. Items were selected and field tested to measure each objective.

Table 14

PMAT Objective Matrix

Topic	Grade					
	1	2	3	4	5	6
Measurement	-Compare length (2 objects); -Compare mass (2 objects); -Inside/outside; -Over/under	-Seriate length (>2 objects)	-Compare volume (2 containers); -Read clock (hours); -Compare area (2 objects); -Measure length (m)	-Measure length (cm); -Read clock (minute and hour)	-Measure length (m, cm, mm); -Compute time; -Measure mass (g, kg)	-Compute area on cm^2 paper; -Compute age (d, m, y); -Read map scale
Numeration	-Compare 2 sets; -Assign numerals; -1-more; -1-less	-Seriate 3 sets; -Compare 2 numerals; -Addition facts; -Exchange (10s, 1s)	-Place-value (10s, 1s); -Addition and subtraction (2 place); -Fractions $\frac{1}{2}$ $\frac{1}{3}$ $\frac{1}{4}$;	-Place-value (100s, 10s, 1s); -Division (1 place); -Multiplication facts; -Multiply by 10	-Compare fractions; -Multiplication (2 place)	-Division (2 place); -Percent; -Add and subtract decimals (money)
Logical Thinking	-Same	-Different	-All	-Some	-And/Or	-If/Then

An initial version of PMAT was trialled. The format and procedures were altered somewhat to ease administration and improve validity. In the final version the first thirty questions were read to the children by the administrator to reduce the English reading load for the younger subject. For grade two the instructions were translated into Pidgin or vernacular by the classroom teacher after each instruction was administered in English. Each student had his own test paper which displayed each item and had a space for the answers. A piece of scratch paper was distributed as well for additional work. Total time allowed for the test was 45 minutes though few grade two children continued working after item 30, the last oral instruction. Most classes were tested separately though occasionally more than one class was brought together and tested in one room. The instructions below were carefully followed by each administrator.

INSTRUCTIONS FOR ADMINISTRATION – PMAT–2

Read the instructions and test items before beginning the test session. Each student will need a pencil. Spare pencils should be available as well.

1. Distribute a pencil, a piece of scratch paper and a copy of the test to each student. Write the name of the school on the board.

2. Read the following instructions:

> Please put the papers on your desk. Don't touch them until I tell you. You are going to do some maths problems. I want you to write your answers on the papers we just passed out.
>
> Look at the front page. Find the line at the top. It says NAME. Write your name on the line. Write the name of your school on the next line. Write your standard (grade level) in the box in line 3. Put an X in the right box to tell if you are a girl or a boy.

3. Wait until everyone has completed writing their name, school and standard (grade level).

4. Read the following instructions.

> Look at the two bananas in the first box. Put an X on the biggest banana. Did you put an X on the big banana? Do you have any questions?
>
> Look at the pineapples in the second box. Count the pineapples. Put the number in the circle. There are 4 pineapples. Did you put the number 4 in the circle? Do you have any questions?

5. Make sure you answer any questions. Caution the children to do their own work. Have them cover their answers as they complete each problem.

6. Read the following instructions:

> I will tell you what to do for each problem. You will put your answers on your paper.
>
> Now turn the page.

7. Read the first thirty items to the class allowing approximately 30 seconds for each. Then go on to number 8.

8. Read the following instructions:

> You will have to read the rest of the problems yourself. Write your answers on the papers. Some problems may be too hard for you. Don't worry. Just leave them and go on to the next problem. Do you have any questions? (pause) Turn your paper over when you have finished. You may start now.

9. Allow 25 minutes for the remaining 25 problems. For standard (grade) two students, collect the tests when it is clear that the students are unable to go on. Most will give up after problem 30.

To score the test each item counts as **one** point except those below:

Problem	Points
6	3
7	2
25	3
43	2
49	2
52	3
53	2
54	2
55	2
Total	21

The total possible score is 67 points (46 + 21).

Three equivalent versions of PMAT were developed and trialled. Four schools in Port Moresby were selected to participate in the study to validate form equivalence. One class for each grade level (two, four and six) was chosen at each school. Each class was randomly divided into three subgroups with 7–10 subjects per subgroup (total n = 287). One version of PMAT was randomly assigned and administered using standard instructions to one subgroup from each of the three classes at each school. The three groups assigned the same PMAT were brought together in one room to help standardize the administration of tests. The mean raw scores for the three versions of PMAT were essentially identical (29.2, 28.5, 28.5 for PMAT 2, 3, 4 respectively). The reliability coefficients between versions of PMAT all exceed 0.88.

The **Test of Arithmetic Skill (TAS)** consisted of 20 graded whole number arithmetic problems, five each for addition, subtraction, multiplication and division. Criteria for each item are listed in table 15 below.

Table 15

Item Criteria for Test of Arithmetic Skill

Item	Criteria	Example
1	Addition fact < 10	3 + 5 =
2	Addition fact > 10	8 + 4 =
3	Two digit + two digit (no regrouping)	46 + 18 =
4	Three digit + two digit (with regrouping)	104 + 38 =
5	Addition of three numbers (2 or 3 digits with regrouping)	256 + 508 + 57 =
6	Subtraction fact < 10	9 – 3 =
7	Two digit subtraction (without regrouping)	27 – 15 =
8	Two digit subtraction (with regrouping)	36 – 18 =
9	Three digit subtraction (double regrouping)	341 – 57 =
10	Three digit subtract two digit with zero in minuend (10s place)	204 – 27 =
11	Multiplication fact (single digits)	3 x 2 =
12	One digit x two digit (without regrouping)	4 x 21 =
13	One digit x two digit (with regrouping)	6 x 34 =
14	Two digit x two digit (with regrouping)	29 x 78 =
15	Two digit x three digit (zero in multiplicand – 10s place)	68 x 207 =
16	Division fact (quotient < 10)	$4\overline{)12}$
17	One digit divisor with quotient n; 10 < n < 20 (no remainder)	$6\overline{)84}$
18	One digit divisor, three digit dividend (with remainder)	$7\overline{)229}$
19	Two digit divisor, three digit dividend (rounded divisor offers good estimate)	$19\overline{)437}$
20	Two digit divisor, three digit dividend (rounded divisor offers poor estimate)	$44\overline{)297}$

Each item counted one point giving a score range of 0 through 20. The TAS was produced in three versions (1, 2, and 3) and administered along with PMAT 2, 3 and 4 respectively. The intent was to provide a secondary measure of computation achievement where addition, subtraction and multiplication exercises were presented in standard vertical format and division left to right ($6\overline{)12}$).

Validity of form equivalence was carried out in the same manner as PMAT and group means (n = 287) were not significantly different (3.9, 4.5, 4.2 for TAS 1, 2 and 3 respectively. The reliability coefficients between versions of TAS were greater than r = .90. The correlation between mean PMAT and TAS results for the trial sample (n = 287) was r = .95.

Language Tests: Three tests designed to provide a measure of English reading ability and oral understanding were administered to all subjects.

Two sentence completion tests were used. One developed for use in Fiji by Elley (1980) and an analogous version developed by Anderson (Assessment Administration Guide, 1980) using sentences from the current Papua New Guinea English syllabus. The instruments consisted of 33 and 25 items respectively. Based on content clues, the children were required to fill in the last word in each sentence by choosing one of four words offered.

For example:

Look at the fish in the
table
eat
water
catch

The tests were administered in groups by grade level. The correlation between the two tests was r = .89 and the mean across all levels were virtually identical, 74.2 vs 74.9 (% correct).

Reliability on the Fiji instrument is reported to be r = .90. The spread of scores between grade levels was more consistent for the Fiji version than the Papua New Guinea version (42%, 76%, 86% vs 37%, 85%, 91% for grades two, four and six respectively). The large jump between grade two and four for the Papua New Guinea version (37%, 85%) may reflect lower instrument validity or the rapid development of English language skills during this period. Regardless, both tests seem to offer a predictable measure of reading ability in the Papua New Guinea context.

A dictation exercise was also administered to all subjects following the reading tests. The intention of the dictation task was to measure in the limited time available a child's "understanding" of spoken English as indicated by his ability to make an intelligible representation on paper of what he heard.

Numerous qualifications and difficulties arise in such an effort. The most obvious is the assumption that if a child can understand spoken English he is able to give some minimal proof on paper of comprehension. The children took to the task readily and in fact produced reasonable written records of the taped passages even in grade two.

All sentences were taken directly from examples given in the approved Form Four English Syllabus for Community Schools in Papua New Guinea. Six sentences with a total of 44 words were recorded by a Papua New Guinea national education officer and administered to students in grades two, four and six. As far as possible, consistent testing conditions were observed. The same tape and taperecorders were used at each site.

The basic rule for scoring the scripts was to "give credit wherever meaning can be made". Points were deducted only if there was a total omission of a word or a non-phonetic spelling which could not reasonably be construed to be a representation of the spoken English word. The possible range of scores were 0 through 44. Accurate spelling was not considered to be a relevant measure for this exercise. Thus slight inversions were given credit and additional letters were not penalised. However, if more than three letters were out of order, a point was deducted. It was therefore possible for a child with very poor handwriting and minimal skills in spelling to score high. The aim was to determine the extent of meaning the child derived from spoken English.

Teacher Measures: Each teacher took the following battery of tests during the pre-implementation inservice course.

1. Primary Mathematics Achievement Test – 1 (Assessment Administration Guide, 1980).
2. Primary Mathematics Achievement Test – 0 (Roberts and Kada, 1979).
3. Aikens Mathematics Attitude Scale (Aiken, 1963).
4. Ravens Progressive Matricies (Australian Council for Education Research, 1966).

The first three tests were administered in a small group set over a period of one week in April 1980. The Ravens Progressive Matricies test was administered in November 1980 after the study was completed.

A detailed survey was completed by each teacher involved in the study during October 1980. The survey requested various demographic and scheduling data. It also included a questionnaire addressing difficulties encountered during the implementation and general methodological and content issues. Space was provided for additional narrative comments on the instructional materials, implementation, classroom observer and inservice activities. Analysis of the survey and tests will be provided in the following section.

Classroom Observers

Five colleagues who were recruited from the United States of America volunteered their services during summer holidays (Northern hemisphere), documenting classroom events and administering assessment instruments at the IMP sites. Their professional training varied somewhat allowing each to bring their unique set of skills and experiences to bear on the task at hand. All had extensive experience observing in elementary classrooms and had been teachers themselves at some point in their careers.

Maryl Gearhart is a developmental psychologist specializing in classroom social interaction and discourse analysis. She is currently an Assistant Professor in the School of Language and Communication, Hampshire College, Amherst, Massachusetts and is nearing completion of a Ph.D. in Developmental Psychology at City University of New York.

Karen Johnson, trained as an anthropologist and as a classroom teacher, is currently designing curriculum and analyzing video-taped episodes for a classroom study on group problem solving being conducted by members of the Laboratory of Comparative Human Cognition, University of California, San Diego.

Paula Levin is a trained anthropologist with interests in cognition and culture. She has done field work among the Tubuai in French Polynesia and urban children in Richmond, Virginia. She is currently an Assistant Professor of Anthropology at Virginia Commonwealth University in Richmond, Virginia.

Julie Lineberger, trained as a sociologist and elementary teacher, has experience teaching in bilingual settings in San Diego, California and Colombia, SA. She is currently a graduate student at Harvard University in the Department of Education.

Robert Rowe has a degree in history, urban and rural development and teacher education, and is currently an elementary classroom teacher in Oceanside, California. He and his students are presently involved in a classroom study involving educational uses of microcomputers. The study is being conducted by members of the Laboratory of Comparative Human Cognition, University of California, San Diego.

SECTION III

RESULTS

RESULTS

A summary of pertinent sections of the field notes and the analysis of the achievement and cognitive data is presented in the following sections:

1. Curriculum Implementation Lesson Summaries
   a) Grade two
   b) Grade four
   C) Grade six

2. Achievement Tests
   a) Differences between grades and schools
   b) Differences between pre-, post-, and retention tests
   c) Item analysis (PMAT 2 and 3)

3. Cognitive Tasks
   a) Differences between schools (cultures)
   b) Relationship to achievement

4. Teacher Survey

CURRICULUM IMPLEMENTATION LESSON SUMMARIES

The following lessons were summarized by by B. Miller-Souviney (1981), based on observations made during the implementation of trial mathematics curriculum materials at the five IMP sites (Gearhart, 1980; Johnson, 1980; Levin, 1980; Lineberger, 1980; Rowe, 1980). Lessons implemented at at least four of the five sites were selected for summarization. Thirty-nine lessons (12 grade two; 13 grade four; and 14 grade six) out of a total of 82 implemented were included in the sample.

A form was developed for use by the reviewer to standardize the documentation procedures. Summary categories included:

1. Lesson number
2. Lesson objective
3. Pre-interview questions
4. Debriefing suggestions
5. Evaluation of the instructional materials
6. Evaluation of the teaching methodology and management
7. Time required for the lesson

Data was extracted from the detailed field-notes and entered in the appropriate column on the form under each site. An overall narrative summary was subsequently prepared under the headings:

1. **Questions** – Pre-interview queries offered by the teacher.

2. **Problems** – Difficulties encountered at one or more sites relative to time, instructional materials, teaching methodology and/or classroom management.

3. **Solutions** – Suggestions made by the teacher and/or observer as to how to improve the instructional materials, teaching methodology and/or classroom management.

Wherever possible the origin of a question or suggestion is indicated by the sites provincial initials (MP, WSP, SHP, WHP, NCD). If a recommendation was unanimous it is followed by the word **All.** Comments (except pre-interview questions) made by teachers are indicated by the phrase "One teacher suggested . . .", followed by the provincial initials. The results are presented by grade level – followed by an overall summary and conclusions.

Several different types of curriculum materials are referred to throughout the report. **Teacher's Notes** were prepared for grades two and four, giving lesson objectives, materials, step-by-step instructions and a copy of the student activity sheets. For grade six the teacher received a copy of the student textbooklet. Each student received a booklet of activity sheets, one for each lesson. A minimal set of learning aids were also provided for each child (base-10 materials, play coins, Kina attribute cards, squared-paper exercise books and measurement devices).

GRADE TWO LESSON SUMMARIES

LESSON – 2:53A – Changing 3 for 1

Questions

1. What if a 5 appears on the dice? (WHP)
2. Why are we using a die marked 0 to 5 when we're working in base-3? (WHP)
3. Where will we get the leaves? (WHP)
4. Are 53A and B the same lesson? (SHP)

Problems

1. No lapboards to write on. (NCD)
2. No workbooks given to children. (NCD)
3. Teachers had to move about the room very often to help students. (All)
4. Too much material to cover in one lesson. (All)
5. No whole group demonstrations were done before breaking into groups. (WSP, NCD)
6. The objective of the lesson was not met because it required too much abstract thought for students. (All)

Solutions

1. The teachers should engage in whole class demonstrations before breaking into groups. (SHP, WHP)

2. Provide more detailed directions for the teachers to minimize errors in interpreting the lesson. (SHP, WHP)

3. The lesson should be broken into three or more lessons so that the children will have ample time to understand the concepts and the game. (SHP, WHP)

4. The materials did not provide for direct comparisons when exchanging "3 for 1 leaf". Money or base-10 materials might be more useful. (SHP)

LESSON – 2:53 C – Changing 10 for 1

Questions

None.

Problems

1. It took too much time to record answers on both the chalkboards and exercise books. (SHP and WHP suggested avoiding the use of both chalkboard and exercise books at the same time.)

2. Concrete materials were not used before representational phase of the lesson. (WSP) To avoid confusion, the students need to "explore" the materials first. (SHP, WSP)

3. The lesson took longer than suggested. (WSP – four periods, SHP – two periods, NCD – two periods.)

4. Students working on their own became confused. (WSP, NCD)

Solutions

1. Use either a chalkboard or exercise book to record exercises, not both.

2. Allow time for the students to make direct comparisons using concrete materials before recording on their lapboards.

3. Have students work in small groups with a leader in each to help those students having trouble.

4. Provide follow-up exercises for the students after the initial demonstration.

LESSON – 2:53 D– Numbers to 20:Place-value

Questions

1. How do you play the game? (WSP)

Problems

1. The teacher explained the game to the group leaders only. The other students were confused. (WSP)

2. The teachers explained the lesson without the children looking at the place-value table in the workbook (no visual aids). (NCD)

3. The teacher took too much time to pass out the materials. (All)

4. The lesson required two periods. (WSP, NCD)

5. Not enough lapboards for each student. (SHP)

6. The teacher explained the lesson with three children using only one board. (WSP)

7. The students took too much time to record their results in their exercise books while playing the game. (WHP)

Solutions

1. The teacher should explain the lesson to the whole class first, using the activity books and base-10 materials.

2. Have the group leaders pass out all the materials beforehand. One teacher suggested making a schedule chart for the whole school so that the materials could be used by everyone without conflict. (NCD)

3. If there are not enough lapboards for each child, use desk tops or divide one board in half for two students. (WHP)

4. While one teacher suggested writing the place-value tables in the exercise book along with the symbols (SHP), another felt recording in both the exercise book and on the lapboard took too much time. He recommended using the lapboards only. (WHP)

5. The teacher should introduce reinforcement activities (additional problems) after the game is played. (WHP)

6. To keep the materials organized, have containers or envelopes available in which to store the base-10 materials. This will help keep the teacher, students and classroom organized.

7. Use an additional die with a (+) on it so children will know what to do with the two numbers. (WHP)

LESSON – 2:53 E – Numbers to 20 Using Money

Questions

None.

Problems

1. The lesson took too long and had to go to second day because the dice were not used during the explanation of the game. (WSP)

2. The teacher did not use the place-value table when explaining the activity. (NCD)

3. The teacher had to move around too much to oversee games. (WHP)

Solutions

1. Pass out materials beforehand – always provide concrete materials (dice, etc.) when required.

2. One teacher suggested setting up a permanent table to store base-10 materials and other aids where students having trouble can go and work with the teachers. Others could go on unsupervised. (WHP)

3. During the lesson introduction have an inner circle play the game and an outer circle observe. This arrangement would reduce the need for the teacher to move about the room excessively during the whole-group explanation stage.

4. Teacher's Notes should be organized so that the overall sequence of the lesson is apparent (eg. logical sequence from place-value to addition). A content/methodology section included before each new topic would help orient the teacher to the overall sequence of objectives. (WSP) Cross referencing between lessons dealing with the same concept later in the year was also suggested. (WSP)

5. Two teachers felt this was the best lesson so far. They felt practice using money was motivating and a valuable real world concern for children. (SHP, WHP)

LESSON – 2:53 F – Counting to 20

Questions

1. What is this drawing (of stick figures) on page 11? (SHP)

Problems

1. The lesson took two days to complete. The children had trouble turning left and right. (WSP)

2. Some children had trouble counting by twos. (NCD)

3. Some students had difficulty "drawing what they did outside" without teacher guidance. One teacher marked the children's drawings for accuracy. (SHP)

Solutions

1. For students who had trouble counting by twos, the lesson was at the right level of difficulty. However at three sites (WSP, SHP, WHP) children had no difficulty counting and the teachers took the opportunity to challenge able students with harder problems (eg. count to 20, 25, then 30, count backwards, count the "easy way" (by twos) and "get into groups of four – pass a ball around five times".)

2. Teachers should provide initial assistance with the students' drawings by discussing what happened outside. Children should be encouraged to use their creativity when drawing.

3. Teachers checking and marking drawings seemed inappropriate. However, ongoing student evaluation should be encouraged where specific skills are being developed. (SHP)

LESSON – 2:53 G – Counting Sets: 1–20

Questions

None.

Problems

1. Instructions in the Teacher's Notes confused two teachers because numbered instructions didn't coincide with exercise numbers in the student workbook. (WSP, SPH)

2. One problem stated "Count the pumpkins". The picture is of coconuts.

3. One teacher seemed unaware that he had the student activity pages in the Teacher's Notes. (NCD)

4. Students are not numbering their problems in their exercise books. Student answers were not separated from the exercise numbers at one school which caused a good deal of confusion (eg. 118 should be 1. 18). (SHP)

5. Some pictures were unfamiliar to non-coastal students. (SHP, WHP)

6. The picture of a hand, writing in an exercise book, at the bottom of the activity sheet was ineffective. The teacher should be instructed that when they see the hand, the students are supposed to record their answers in their exercise books. (WHP)

Solutions

1. Instruct the teachers to look at student's activity pages when giving instructions to students to avoid confusion. Also, teachers should not read aloud the instruction numbers in the Teacher's Notes.

2. Clearly state to teachers that the Teacher's Notes contain the student activity sheets.

3. Instruct the students to number their books before they start their exercises and to draw a vertical line after the problem numbers to separate them from their answers.

4. The teachers should discuss the worksheet with students before the lesson begins. Include pictures of peanuts, pigs, chickens and trucks for highlands children. (SHP)

5. Teachers should tell the children to record their answers in their exercise books whenever they see the "hand". (WHP)

6. Teachers at three sites reviewed the previous lesson (counting to 20) and conducted evaluation during the lesson. Both should be suggested in the Teacher's Notes. (SHP, WHP, NCD)

LESSON – 2:53 I – Addition Facts to 10

Questions

None.

Problems

1. All sites felt the lesson covered too much for one period.

2. Several teachers took too long to pass out the materials. (WSP, SHP, NCD)

3. The idea of place-value exchange was not explained to children as part of the lesson. (SHP, WHP, NCD)

4. One teacher had the students put the base-10 materials in the place-value table on the activity sheet. The boxes were too small making it awkward for the students. (WSP)

5. The same teacher omitted the representational level of the lesson as well. He focused on the answer not the process. He used the base-10 materials superficially, focusing instead on the symbolical answer. The teacher had the students use only their activity sheets instead of their lapboards and passed out the base-10 materials **after** the explanations, stressing writing the answer "quickly". (WSP)

6. At two sites no reference was made to the activity-sheet pictures. (NCD, SHP)

Solutions

1. The activity should be divided into two lessons. Teach addition with sums less than 10 first and then introduce regrouping.

2. Specific instructions should be provided in the Teacher's Notes regarding classroom management and material distribution.

3. The teacher should demonstrate manipulative procedures to the entire class on the chalkboard. Using a teacher prepared place-value-tables worksheet would encourage students to concentrate on filling in the appropriate information. (WHP)

4. Manipulating the base-10 materials during whole-group demonstrations as well as individual activities must be stressed in the Teacher's Notes to help teachers understand the importance of concept development.

LESSON – 2:55 A – Ordering Time

Questions

None.

Problems

1. The lesson took too long at all sites.

2. Glue, scissors and even paper were scarce and, when available, took long to pass out.

3. The children were not able to draw, cut and paste the pictures in the time allowed.

4. Recording the order of "finishers" in the race was confusing. (WSP, WHP, NCD)

5. One teacher had trouble distinguishing between actions (run, walk, crawl, hop, walk backwards). Consequently, the students were confused. (SHP)

6. One teacher had the students merely imitate the actions, without actually "racing". The order of finishers was obviously confusing. (NCD)

7. One teacher had the students record who came in first only. (WSP)

Solutions

1. Have the picture of the contestants drawn and cut out before the race (the teacher at WHP suggested making them during an art lesson).

2. Have students simply draw the time-line and write the names of the finishers (run, hop, walk, etc.) in the proper order. (WHP)

3. Have the students perform each action prior to the race. (SHP) One teacher suggested lining up the finishers after the race in single file in the correct order so the time-line can be completed more easily. Do this for each group of five. (WHP)

4. Have only one group race while the other students watch. Stress the order of finishers. Have the students predict the order before the race.

5. Label the racers with headbands inscribed with the appropriate action. (WSP)

6. After the race give the finishers two "new names" (eg. run, 1st). It is easier to transfer the information to time-line. (WHP)

LESSON – 2:55 B – Ordering Age

Questions

1. Can I use youngest, younger, young, oldest, older, old? (WHP)

Problems

1. Teachers had difficulty explaining the terms "youngest" and "oldest" in English. (WHP, SHP, WHP)

2. Lesson included too many parts to be co-ordinated by grade two children. (All)

3. Some children had difficulty copying the time-line. (WHP, NCD)

4. Some students found it difficult to recognise the pictures. The sexes were unequally represented in the graphics. (SHP)

Solutions

1. Teachers should be encouraged to use Pidgin or **tok ples** when explaining difficult terms to students.

2. Have three, four and then five children line up in order from youngest to oldest before presenting the activity sheets. It may be necessary to use a few children from older classes. (WHP)

3. Split this activity into two or more lessons – one to prepare the pictures and one to create a time-line. A discussion about the stages of growth for boys and girls might follow. (SHP)

4. The Teacher's Notes should include a procedure for drawing a time-line of a specified length. (Children and teachers confused points with line segments – eg. five points instead of five spaces.) One teacher had his students count spaces (5) between vertical lines in their exercise books. (WHP)

5. Use all the same sex or more than one female in the pictures. The one female seemed to confuse many students. (SHP)

LESSON – 2:56 A – Ordering Groups of Things (Sets)

Questions

None.

Problems

1. The terms "smallest" and "largest group of things", were confusing. Teachers felt students confused the size of the objects with the size of the sets. (WSP, SHP, WHP)
2. Copying pictures of sets takes too long. (WHP, WSP)
3. Too many steps were required for this activity (drawing, counting, marking sets and recording answers). (WSP)

Solutions

1. Change the comparative terms to "fewest" and "most".
2. Instead of pictures of pigs, use something closer in size to other objects. (SHP)
3. Do this lesson orally as an introductory activity for a lesson on sets and ordering. (SHP) Teacher's Notes should include introductory examples. (WSP)
4. Instructions should stress drawing an arrow from the previous group, as opposed to returning to the smallest set each time. (WHP)
5. One teacher introduced this lesson by correcting a mistake found in the student activity sheet. This seems like a good suggestion should teachers or students find mistakes in curriculum materials. (WHP)
6. An appropriate extention for more-able-learners might involve a discussion of **how many** more objects are in one set than the other. (SHP)

LESSON – 2:56 B – One-More and One-Less

Questions

1. What if 1-Less is rolled on the first turn? Do you skip a turn? (WHP)

Problems

1. It was unclear to teachers what to do if 1-Less is rolled on the first move. (WSP, WHP)
2. One teacher commented that we should use the word "die" instead of "dice" since we are using only one. (WSP)
3. In groups of six, not all the students participated. "Leaders" seemed to do the moving for everyone in that group. (WSP) It took a long time for a winner to be established. (WSP, NCD)

Solution

1. Explain in Teacher's Notes that a six-sided die should be used. A picture of one (all six sides) would be most helpful. (WSP, WHP)

2. Include in rules of the game a specific example of a move (eg. "Suppose you're at 6 . . ." or "At the start, suppose you roll 1-Less . . ."). (WSP, WHP)

3. If only two or three students played in a group, more practise with skills would be possible and a winner would be established sooner. Also, there would be less chance for students to passively watch the game.

4. Suggest possible ways for the teacher to present the game to the whole class before the students break into groups.

5. Suggest possible extention activities (eg. have the students verbalize what they are doing – "add one, subtract one" – or write a number sentence to record moves). (WHP)

LESSON – 2:56 D – 1-More and 1-Less

Questions

1. Why start with (the number) 3? (NCD)

Problems

1. Copying the diagram is too complex and consequently takes up most of the lesson time. (WSP, NCD) One teacher alleviated the problem by writing only the answers in the exercise book. (SHP)

2. One teacher had trouble drawing the diagram on the chalkboard. (SHP)

3. One teacher felt the students would be confused by the arrows which represent addition and subtraction of 1. (WHP)

Solutions

1. Simplify the diagram to make it easier to copy (eg. fewer circles set in a straight line). (WHP)

2. If a copying machine is available, reproduce the diagram for the class. (WHP)

3. The teacher should be instructed to draw the diagram on the board **before** the lesson begins.

4. Label the arrows with 1-More and 1-Less to simplify the instructions. (WHP)

5. The teacher should discuss the meaning of the arrows (1-More and 1-Less) with the class prior to copying diagram.

GRADE FOUR LESSON SUMMARIES

LESSON – 4:144 A – Introduce $\frac{1}{2}$ and $\frac{1}{4}$

Questions

1. What materials should we use; (perhaps) kaukau (since) bananas are too precious? (MP)

2. Could I say "Work in **groups of 2**" rather than **pairs**? (WHP)

Problems

1. Appropriate materials were scarce. Local vegetables and fruits are too valuable and plasticine was unavailable at three sites.

2. The lesson took longer than 30 minutes at all sites (WHP – 50 minutes, NCD – three periods).

3. Teachers did not put an equal number of students in each group. (WSP, SHP, NCD)

4. One teacher drew an example of one-third on the chalkboard showing three **unequal** parts. (WSP) **Equality** of parts is not stressed. (WSP, SHP)

Solutions

1. Include alternatives in the "Materials Needed" section. If these are not mentioned, shy or insecure teachers may skip the concrete experiences and go directly to the worksheet. (MP)

2. Allow more flexibility in scheduling the lesson.

3. Organize into groups of four first, then the students can pair off for the "one-half" activity. Change the lesson sequence to "one-fourth" then "one-half". (NCD)

4. In the instructions to the teacher, stress the importance of **equal** parts when defining fractions. (WSP, SHP) Have the children verbalize their results after dividing the pieces. (WSP)

5. Include a narrative example in the instructions (eg. "Two children want to buy a meat pie. They only have enough toea for one"). The story gives students a **reason** for dividing things equally. (NCD) One teacher makes the important observation that when a teacher understands the material, the children do better. (SHP)

LESSON – 4:144 B – Introduce $\frac{1}{3}$

Questions

1. Can you divide a circle (into thirds)? (MP)

2. What does it mean, make different **plasticine** shapes? (WHP)

3. Are these (activity sheet figures) examples (of plasticine shapes)? (WSP)

Problems

1. Both teachers and students had difficulty dividing objects into thee **equal** parts. (MP, WSP, SHP, WHP)

2. Appropriate materials were not readily available. (MP)

3. The lesson took longer than 30 minutes. (MP)

Solutions

1. Include how to divide an object into thirds [eg. "Make sure your object a) has **three** parts, b) has three **equal** parts, c) **any** three equal parts (more than one way to cut)]. (MP)

2. Provide **answers** to the dividing-objects exercises (circles, rectangles, etc.) in the Teacher's Notes. (SHP)

3. Introduce the lesson using a ractangle since it is easier to divide into three **equal** parts.

4. One teacher made the comment that the grade four lessons were the best prepared and most straightforward. (WHP)

LESSON – 4:144 C – Making $\frac{1}{2}$, $\frac{1}{3}$ and $\frac{1}{4}$ of a Whole

Questions

None.

Problems

1. Students continue to have difficulty dividing figures and objects into **equal** parts. (All)

Solutions

1. Include more examples in the Teacher's Notes using different shapes. (MP)

2. Instead of **"Draw lines to show each fraction"**, the directions should read **"Shade in each fraction"**. (MP, SHP)

3. Suggest that teachers use concrete materials to introduce this review lesson (eg. paper figures). **Stress the equality of parts.** (NCD)

4. Include an extention activity involving comparisons of fractions (eg. "Would you rather have $\frac{1}{2}$ of a sugar cane or $\frac{1}{3}$?). (MP)

5. Stress the need for an evaluation of the lesson and of individual student progress. Perhaps have several students do problems on the board and have the class check the answers. Teachers should consistently check the exercise books as well. (NCD, WHP)

6. Include answers for all exercises in the Teacher's Notes. (SHP)

LESSON – 4:144 D – Recognise $\frac{1}{2}$, $\frac{1}{3}$ and $\frac{1}{4}$ of a Whole

Questions

None.

Problems

1. A general concern was voiced that teachers were not adequately checking students exercise books to see if concepts were being learned. (All)

Solutions

1. The teachers at four sites (WSP, MP, SHP, NCD) engaged in little or no ongoing evaluation whereas the teacher at the fifth site (WHP) religiously observed student work during class time and checked their exercise books frequently. Suggestions to encourage good evaluation practices should be included for each lesson.

2. Recognising Fractions (144 D) was an easier lesson than Making Fractions (144 C). The two lessons should be reversed. (MP, SHP) One school completed both lessons in one period. (WSP)

3. Change the directions from, "Write the fraction" to "What fraction is **shaded** in the figure?" (SHP)

LESSON – 4:144 E – Introducing $\frac{1}{2}$ and $\frac{1}{4}$ of a Set

Questions

None.

Problems

1. The teacher does not demonstrate $\frac{1}{4}$ as requested in some problems so the students circle $\frac{1}{2}$ of all groups as in the worked example. (SHP)
2. Students had trouble with one-fourth of twelve (no. 7). (MP, SHP, WHP)
3. One teacher asked many questions during the introduction of the lesson resulting in a number of chorus responses. It was unclear who understood the procedure.
4. The terms **"equal piles"** and **"equal groups"**, used interchangeably in this lesson caused some confusion. (SHP)
5. Many students had difficulty consistently making **equal** groups. (All)
6. One teacher implemented 144 E ($\frac{1}{2}$ and $\frac{1}{4}$) and 144 F ($\frac{1}{3}$) as one lesson. (MP) The students did not do as well as those at sites where the lessons were introduced over two periods.

Solutions

1. The Teacher's Notes should stress that each group must have the same amount. (SHP)
2. Circling **each** group should be stressed and modelled in the worked examples.
3. The Teacher's Notes should suggest introducing the lesson with a whole-group demonstration.
4. The teachers should be encouraged to evaluate student progress by asking **individual** students to demonstrate understanding.
5. Start with groups of four and pair off later. (NCD)

LESSON – 4:144 F – Introducing $\frac{1}{3}$ of a Set

Questions

None.

Problems

1. Students had trouble making groups with **equal amounts.** (All)

2. Students circle groups of **three**. (WSP, SHP, WHP, NCD)

Solutions

1. Demonstration examples should involve 15 or 18 objects, not 9.

2. Students should be instructed to **circle** and **label** each group.

3. Provide more practice examples in the Teacher's Notes different from the worked exercises on the activity sheet.

4. Encourage the use of counters by students as they work on their exercises.

5. Stress that teachers should evaluate **individual** students both orally and by reviewing their exercise books to be sure that the concept is being learned.

LESSON -- 4:145 A – Sorting by Two Attributes

Questions

None.

Problems

1. The lesson took longer than expected (WSP – three periods; WHP – rushed lesson; NCD – didn't finish lesson).

2. Most students had trouble sorting because the teachers didn't introduce the lesson clearly. The teachers seemed to have trouble with the language ("and", "or", "not") themselves.

3. Teachers didn't check to see if the sets of Kina Cards were complete. One teacher had to stop the lesson to find missing pieces. (WSP)

4. One teacher was confused whether to use the **name** of the pictures as labels or the **shapes**. (SHP)

5. Desk space was a problem at three sites. (WSP, WHP, NCD)

Solutions

1. Divide the lesson into two parts. Do exercises 1 and 2 the first day. Let the children work on numbers 3 and 4 the second day. (WHP)

2. The teacher should work through all the problems before the lesson. Answers for all the exercises should be included in the Teacher's Notes. (MP, WHP)

3. Kina Cards should be organized into envelopes by the teacher or students **before** the lesson begins. (MP, SHP, WHP)

4. One teacher found working in pairs using small chalkboards to be successful. (MP) Using the floor would also be a good idea. Another teacher found working individually was best because the teacher could observe individual progress. (SHP)

5. The worked example is not clearly labelled like the exercises on the student activity sheet. (SHP)

6. One teacher, while trying to reduce the amount of teacher talk, felt the lesson failed because he didn't explain the procedures thoroughly enough. (NCD)

LESSON – 4:145 B – Sorting by Two Attributes

Questions

None.

Problems

1. Lesson took longer than expected. (WSP, NCD)
2. Students had difficulty with negation ("not"). (WSP, WHP)
3. The desks were too small for the materials. (All)

Solutions

1. Split the lesson into two parts – a whole-class introduction, followed by small-group exercises.
2. Begin with a review of the previous lesson. (WHP)
3. Two teachers had the students work on the floor. This procedure proved most successful. Students got to travel along "real" roads using actual Kina Cards. One teacher compared this activity with travelling to Mount Hagen and pointed out the importance of reading "city signs". (WHP, MP)
4. Working in groups encourages a game-like atmosphere where students tend to correct each others errors. (SHP, WHP)
5. To be consistent both the outline shape and the picture (or name) should be included in exercises involving Kina Cards. Road signs should begin with a capital letter. (SHP)
6. Background on importance of classification skills should be included in the Teacher's Notes. Teachers often view topics such as geometry, measurement and classification as less important than number operations. The relevance of such topics to the effective development of problem solving, logical thinking and language skills should be pointed out in order to encourage teachers to take such activities seriously.

LESSON – 4:145 C – Sorting by Two Attributes

Questions

None.

Problems

1. One teacher thought the lesson was on map reading. (WSP) Another felt teachers with less in-service training (than she had) might misunderstand the objective. (MP)
2. The lesson took longer than expected. (WSP – 2 days; NCD – didn't finish)
3. Problem no. 2 is missing a "not" label.

4. Two teachers had trouble interpreting the exercises and asked the observer to explain the problem to the class. (MP, WSP)

5. The students drew the roadways too small to use the Kina Cards effectively. (MP, WSP, SHP, NCD)

6. The teacher felt it took too long for the students to complete the exercises working in groups and taking turns. He had them do the activity individually. (WSP)

Solutions

1. Stress the lesson objectives in a way which shows **why** this skill is important and how it relates to previous activities.

2. Divide the activity into two lessons – a whole-group introduction followed by small-group exercises.

3. Use arrows to indicate the directions to follow on the roadways. The Teacher's Notes should provide extra examples and solutions to the student problems. (MP)

4. Specifically state in the Teacher's Notes that the pictures are "roadways".

5. Stress the importance of a whole-group demonstration to introduce the activity.

6. Most teachers used the idea of a "rubbish bin" to discard the cards that do not make it to the house. The students need some place to put the unsuccessful cards. (SHP)

7. One teacher was very successful in implementing this lesson by drawing life sized roadways on the floor for the children to walk along. It alleviated the problem of recopying the diagram for each exercise and was very motivating. (WHP)

LESSON – 4:149 C – Introducing Both-Way Rule (Commutative Rule)

Questions

1. Should the students use the activity book? (MP)

Problems

1. The lesson contained too many problems. (All)

2. It took a long time for the students to draw the multiplication blocks. Most sites were not able to complete the activity in one period. (MP, WSP, SHP)

3. One teacher labelled the 2 x 3 block, 3 x 2, confusing the students. (WSP)

4. One teacher called the blocks "squares" (probably confused with "squared paper"). (WSP)

Solutions

1. Split the lesson into two parts or provide four picture exercises and only four symbolic problems. (SHP)

2. Stress the use of the word "block". Have the students paste completed "blocks" into their exercise books to keep.

3. One teacher explained the commutative rule by stating that there are two "stories" for each multiplication problem. (WHP)

4. Allow sufficient time for cutting the blocks.

5. One teacher suggested not including the number labels on the blocks in order to allow the students to **discover** the array model for multiplication. Also, circles used as answer frames were confused with zero. Use a square or a question mark. (WHP)

6. Encourage the teacher to have the students cut out the multiplication blocks before the class begins (recess, lunch or after school).

LESSON – 4: 149 D – Constructing the Multiplication Table

Questions

1. Where will the students start cutting from? (WHP)

2. Does every individual block have to be cut? (SHP)

Problems

1. One teacher could not figure out which blocks were to be cut. He didn't understand the application of the Both-Ways rule. (WSP)

2. The lesson took much longer than expected (WSP – three days or six class periods; WHP – two lessons; NCD – three lessons).

3. The students had difficulty applying the Both-Ways rule when cutting out the blocks. (All)

4. Students chose blocks to cut out randomly (SHP) and didn't arrange the blocks on the table correctly. (All)

5. Teachers didn't clearly explain goal of lesson. (All)

6. At first the teachers didn't understand the procedure for placing the blocks on the multiplication table. The instructions were unclear about "lifting up the corner" and writing the answer on the table. (SHP, WHP)

7. Students did not work in groups as recommended and could not finish all the cutting. (WSP)

8. The lesson failed across four sites because instructions were too complicated and the teachers were unclear about exactly what to do. (WSP, SHP, WHP, NCD)

Solutions

1. Instruct the teachers to make lists of which blocks each student must cut out. Include a list in Teacher's Notes. (WHP, SHP, NCD)

2. Begin the lesson by demonstrating the Both-Ways rule, using example blocks to show, for example, why 2 x 3 and 3 x 2 is the same. No need to cut out both.

3. Divide lesson into two or three – one or two spent cutting out blocks (or outside class) and another one to fill in table.

4. Have students work in groups so that each group makes the blocks for one complete row. One class set of blocks can be constructed and used to "fill in" a class multiplication table. (WHP)

5. Teachers should arrange to construct the blocks prior to the lesson in order to save class time.

6. The Teacher's Notes should list the actual steps of lesson and explain objectives more clearly.

7. One teacher felt the table should be filled in first. Then have the students construct the blocks. This process would clarify the Both-Ways rule. (WHP)

8. On the student worksheet provide a complete example of the multiplication table and the "lifting a corner" graphic as in Teacher's Notes. (SHP)

9. Encourage teachers to do extra preparation for these lessons.

LESSON – 4:164 A – Addition (Revision)

Questions

None.

Problems

1. There were too many exercises for one lesson. (All)

2. Some students accidentally added in the place-value table "label-blocks" when doing the addition problems.

3. Teachers instructions do not describe the addition procedures using base-10 materials as in the grade six Teacher's Notes. (MP) One teacher did not use the base-10 materials at all. (WSP) Students at three sites didn't use the base-10 materials after being introduced to them by the teacher. (WSP, SHP, WHP)

4. Students had difficulty writing the answer in the "workspace", then regroup and record the results in the answer space. (WHP)

5. Students made simple mistakes with addition facts. (WHP, SHP, WSP)

Solutions

1. Separate the lesson into two parts: one using base-10 materials only, followed by problems using squared paper. (MP)

2. To avoid adding in the place-value column labels, draw a picture of a unit and ten-rod above each column rather than using the actual materials.

3. If one lesson involved **only** the use of the base-10 materials this important step would not be as easily skipped.

4. Include a worked example in the Teacher's Notes. (SHP)

5. Encourage revision of addition facts prior to this lesson.

6. Suggest that the second activity sheet (164 A-2) be given for homework if students are unable to finish in class. (SHP, WHP)

LESSON – 4:164 B – Subtraction (Revision)

Questions

None.

Problems

1. There were too many exercises for one lesson. (All)

2. Instructions do not demonstrate the use of base-10 materials for subtraction as in the grade six Teacher's Notes. (MP)

3. Some students forgot to remove a ten-rod after putting 10 ones in the one's column. (MP)

4. Most students at two sites did not use the base-10 materials. Many appeared not to need them. (SHP, WHP)

5. Some students forgot simple subtraction facts. (WHP)

Solutions

1. Divide the lesson into two or more parts: subtraction using base-10 materials; then a lesson involving simple subtraction followed by another involving subtraction with regrouping.

2. Provide detailed instructions (as in grade six) showing procedures for using the base-10 materials.

3. Suggest a "bank analogy". If you borrow 10 ones from the bank, you must put the same amount (a ten-rod) back. (MP)

4. An introductory lesson should involve using **only** base-10 materials. Though some children seemed to progress well on worksheets, doing the problems "the old way" in their heads, the question remains as to whether they can apply their understanding of place-value and regrouping to more difficult problems later. These exercises seemed to be revision for SHP and WHP students.

GRADE SIX LESSON SUMMARIES

LESSON – 6:1 – Counting Systems

Questions

1. Is page one the worksheet for the lesson? (SHP)

2. Why does (the text) say look "above" when picture isn't above, it's on the previous page? (WHP)

Problems

1. At the beginning of the lesson one teacher had the students look only at the table. He didn't mention the picture showing the body-counting system until a student suggested it. (WSP)

2. Some students got their right and left hands mixed up. (WHP)

Solutions

1. Because most teachers follow the step-by-step instructions closely, include two sections: one which lists the objectives and teaching methods and a separate section which lists specific sequenced instructions. (WSP)

2. It would be better to introduce lesson 6:2 (local counting system) first as it relates more directly to the students' world. (WSP)

3. All sites felt it would be better to have the students using their **own** counting systems as part of this lesson. Instructions should encourage using local counting systems. Include a general section that describes counting in Motu and Pidgin as examples. Perhaps a local villager could be invited to the school to teach the indigenous counting system.

4. Instructions should state the origin of example counting system.

5. Label the left and right hands in the picture.

6. A nice discussion occurred about the standard numeration system, the Roman numeral system and Imbonggu tally number system. Much enthusiasm was generated by this discussion because the teacher was knowledgeable about the local system. (SHP)

LESSON – 6:2 – Counting Systems

Questions

1. What language do the students use the chart in? (SHP)

Problems

1. Two teachers did not have the students work in groups so there was no interaction or class posters. (WSP, NCD)

2. Students were not knowledgeable about their own **tok ples** counting systems. (SHP, WHP, NCD)

3. Teachers had difficulty with term "meaning" in the third column of the body parts chart. (WSP, WHP, NCD)

4. Students took a long time to draw the table even though the teachers hurried them along. (WHP, NCD)

5. Only one student knew more than one indigenous language. (WSP, SHP)

Solutions

1. Suggest that students go to a village elder and find out about their local counting system. Or better still, invite a villager in for the day who is knowledgeable and willing to supervise and instruct groups. (SHP, WHP)

2. Teachers should be reminded to be patient with their students.

3. Encourage teachers to prepare a chart of his own village's counting system before the lesson. (WHP)

4. Suggest using four columns in body-parts chart. Add "Meaning in **tok ples**" and "Meaning in English". This seemed to clarify the chart for the students. (WHP)

LESSON – 6:4 – Roman Numerals

Questions

None.

Problems

1. One teacher thought two items of information (no. 6 and no. 7) were questions for the students to answer. (WSP)

2. The students did not know meaning of the word "symbol". (WSP, SHP)

3. "Hindu" is mis-spelt in the table on page 8.

4. This lesson is too short for older students. (SHP, WHP)

5. Students did not know their own or other counting systems well. (SHP, WHP)

6. The students didn't seem to follow-up when the teacher asked them to speak with their family about the local counting system. (SHP, WHP)

Solutions

1. Include a discussion of Hindu-Arabic symbols at beginning of the lesson along with Roman numerals.

2. Change the word "symbol" to "sign". (WSP)

3. Provide the opportunity for extension work by leaving space for adding more numbers or add another column labelled "My Own Counting System". (SHP)

4. Instruct the teacher to provide such a chart for students to fill out with family members.

5. Since the teachers seemed to follow the lesson instructions verbatim, include a statement like "Discuss", "Think", or "Talk" when you would like a discussion generated. (WSP)

LESSON – 6:5 – Base-10 Counting

Questions

None.

Problems

1. One teacher had trouble translating pictures of base-10 materials into numbers. (MP)

2. One teacher had trouble with "208" (saying 28). (MP)

3. Base-10 materials were not used. (SHP, MP, WSP)
4. Some students didn't realise ten 10-rods equal one 100-raft. (NCD)
5. Some students had trouble with place-value. (WHP)

Solutions

1. Introducing money (1t, 10t, 1K) would be a useful analogy. (MP)
2. Instructions for the teacher should suggest doing more introductory exercises with "making lots" using only base-10 materials before assigning the problems on p.11. (WSP)
3. Perhaps the lesson should be split into two: introduce the table and base-10 materials first, then assign the exercises the following day.
4. The chart (0–99) is confusing because it resembles a 100-raft. It should include the numbers 1–100 with a discussion of zero in another place.
5. Suggest other whole-group activities to do using the table. (WSP)
6. Set up pictures of base-10 materials in place-value houses to further stress the meanings of ones, tens and hundreds. (WHP)

LESSON – 6:8 – Addition Revision

Questions

1. Do we give students squared paper or do they draw (the tables) in their books? (NCD)

Problems

1. The students did not use squared paper to make the addition table so the lesson took longer than planned.
2. Some students had trouble with the zero column on the addition table. (WHP, SHP)
3. A few students had difficulty knowing where to put the correct answer on the table. (WHP)

Solutions

1. Using squared paper to make tables must be stressed in the Teacher's Notes.
2. Plan a separate lesson on addition with zero prior to the current lesson.
3. Use arrows to show how to place the correct answer on the table.
4. Provide more exercises to extend the lesson. It proved to be quite easy at most sites. (WHP, SHP)
5. This lesson is an example of one which teacher evaluation of the individually completed charts should be stressed. Two sites reported good teacher evaluation procedures (SHP, WHP), while one teacher only put the correct answers on the board. (NCD)

LESSON – 6:10 – Subtraction Revision

Questions

1. What does the heavy line towards the bottom of the subtraction table mean? (SHP)

Problems

1. The most frequent problem encountered involved understanding the significance of the shaded areas in the subtraction table. (All) One teacher thought this was a lesson in memorization. (WSP)
2. The lesson took longer than expected because the table took a long time to draw.
3. It is difficult to see the shading of the lower shaded area. (SHP)
4. One teacher was confused about subtracting using zeros. (WHP)
5. Students had some trouble determining where to put their answers. (WHP)

Solutions

1. Provide the answers in the Teacher's Notes to questions regarding the shaded areas in the table. Interestingly enough, many students found the pattern quite easily. (MP, WHP, NCD)
2. Give explicit instructions as to how to fill in the table. Use arrows to denote where the answers to several examples should be placed. Stress that an introduction of this sort is very important for the class.
3. Stress the need for patience on the part of the teacher while the students copy the chart. Perhaps the table could be made prior to the lesson.
4. One teacher suggested including more subtraction problems as follow-up to provide sufficient practice. (MP)

LESSON – 6:12 Addition with Regrouping

Questions

None.

Problems

1. One teacher first had the students add 17 + 25 using all ones with no discussion of place-value. Some students subsequently had difficulty with symbolic regrouping. The teacher seemed reluctant to allow the use of base-10 materials to solve the problems. (WSP)
2. A few students added the tens first. (NCD)

Solutions

1. Have the teacher begin the lesson with a whole-group introduction on the chalkboard. Those sites that introduced the regrouping procedures to the class had no major difficulties. (SHP, WHP, NCD)

2. When using base-10 materials, the number symbols should be recorded **inside** the place-value table, not along the side. This procedure seemed to afford a smoother transition to numerical problems. (WHP)

3. Demonstrate that using base-10 materials gives the same answer as using symbols. Show both processes by doing the same problem side-by-side.

4. Stress that base-10 materials should be used initially to solve all problems and later to check answers.

5. Teachers should be encouraged to evaluate student progress. (SHP, WHP, NCD)

6. One teacher commented that students in Papua New Guinea are taught to carry the ten to the **bottom** number, not the top as in the IMP model.

7. Most teachers felt this was an excellent lesson and the base-10 materials were very useful for grade six.

LESSON – 6:13 – Addition With Regrouping

Questions

None.

Problems

1. Some students had difficulty operating with hundreds since no preliminary explanation was offered by the teacher. (WSP)

Solutions

1. An example should be provided in the Teacher's Notes involving regrouping in the 100's place. (WSP, WHP, NCD)

2. All sites stressed the need to provide a whole-class introductory demonstration before beginning individual work. Teacher evaluation of individual student understanding was considered especially important in this lesson, because of the importance of the objective. (WHP)

3. Use different colours of chalk for different place-value houses. (NCD)

4. Stress the relationship between base-10 manipulations and carrying out symbolic work in place-value tables.

5. The exercises in problem 7 should be labelled (a, b, c, d) across the page. (WHP)

6. The base-10 lesson for adding with regrouping seemed to be presented most clearly in the grade six materials. The teachers felt the Teacher's Notes were "straightforward" and seemed enthusiastic about doing addition this way.

LESSON – 6:15 – Addition Palindromes

Questions

1. How do you pronounce "palindromes"? (WHP)

Problems

1. One teacher called 421 and 124 the "same". The students seemed confused. (WSP)

2. One teacher began the adding process with a palindrome (626). The first and last numbers are supposed to be different. (WSP)

3. One teacher saw this activity as having no purpose. (WSP)

4. Several students didn't finish all the problems. (SHP, NCD)

Solutions

1. Provide a pronunciation key for the word "palindrome" in the Teacher's Notes.

2. Most sites felt this lesson was straightforward. One teacher suggested moving the exercise involving listing word and number palindromes (7 and 8) to the end of the lesson. (SHP)

3. Emphasize that it sometimes takes more than one step to arrive at a palindrome solution. (WSP)

LESSON – 6:16 – Subtraction With Regrouping

Questions

None.

Problems

1. One teacher seemed unprepared to teach this lesson. He neglected to demonstrate the entire base-10 subtraction procedure. He demonstrated the manipulation as far as changing tens for ones then instructed students to write the answers. When the children showed confusion, the observer was called in to explain. Finally, a student demonstrated the procedure to the class. (WSP)

2. The numbering of the exercises confused the students. Problems are numbered a) and d) on page 38, beginning with b) on page 39.

3. The teacher demonstrated a symbolic addition problem first in order to show the difference between addition and subtraction. The students became confused as to how to do the subtraction problems. (NCD)

Solutions

1. The need for adequate teacher preparation prior to the lesson must be stressed. Clearly most base-10 number operation work needs appropriate teacher in-service.

2. Renumber the exercises across the page.

3. Working through problems with base-10 materials needs more emphasis. Until the teacher recognises the importance of concrete manipulations, symbols will remain the preferred method since it takes "less" time.

4. One teacher suggests that the place-value "house" should have a "working space" (as in the squared-paper tables) for regrouping. (WHP)

5. Perhaps the subtrahend should be represented using base-10 materials in an area on the right side of the place-value house. Then appropriate ones and tens can be brought down from the minuend (Souviney, Keyser and Sarver, 1978). This model may provide a better analogue for the symbolic algorithm.

6. Suggest that teachers simultaneously explain to the whole class both base-10 materials and symbolic place-value tables. Some sort of convenient display system such as a magnitic display board would be very useful for this purpose.

LESSON – 6:17 – Subtraction With Regrouping

Questions

1. Must the students also write their answers in their exercise books? (SHP)

Problems

1. One teacher did not explain the term "regrouping" to the students. (WSP)

2. Only one example was worked out with the whole class. Many students were confused. (WSP)

3. One teacher had difficulty explaining that the phrase "six from nine" means: 6 – 9. (WSP)

4. Many students were unable to complete all the problems in the time allowed. (SHP, WHP)

5. One teacher felt the lesson covered too much material for one lesson (3 and 4 place numbers). (WHP)

6. Students had difficulty copying problems onto squared paper and crossing out the tens during regrouping. (WHP)

Solutions

1. Suggest including more two-place subtraction examples in the whole-group lesson introduction. (WHP)

2. Divide the lesson into two parts: one dealing with "2 houses", another with "3 and 4 houses". Also reduce the number of exercises so the students can finish during class time and the teacher can evaluate their progress.

3. The exercises should be numbered from left to right. (WHP)

LESSON – 6:19 – Subtraction Practice

Questions

1. I am not too sure of the steps (in this lesson). (WHP)

Problems

1. Students attempted to subtract a large number from a smaller one and became confused. (SHP, WHP, WSP)

2. The goal of the lesson wasn't explained well so the students were not motivated to find the "Magic Numbers". (WSP)

3. Many students made careless addition and subtraction mistakes. (WHP)

4. The lesson was not finished since an NBC broadcast interrupted the schedule. It happened frequently at this site. (NCD)

Solutions

1. Directions should stress subtracting the smaller number from the larger after reversing the digits. Include an example (eg. 276) that demonstrates putting the reversed number on top. (SHP, WHP)

2. Squared paper should be used to help with the computation. (SHP, WHP)

3. A whole-class teacher demonstration is very important here. One teacher did three examples, each time giving more responsibility to the students for completing the problems. (WHP)

LESSON – 6:21 – Practising the Multiplication Facts

Questions

1. Do we use one or two dice? (WSP)

2. I have confusion about tomorrow's lesson. Why do the students count to 20? (NCD)

3. How do I start the game off? (NCD)

4. Does the Both-Ways rule apply? (NCD)

Problems

1. One teacher had difficulty organizing the students into groups. (WSP)

2. One teacher had the students use two dice to play the game and did not know what to do with the two numbers on the dice. (WSP)

3. Students mistakenly began by finding multiples of the number on the die on the gameboard. (SHP)

4. The students counted to 20 very quickly in order to prevent the player from writing any number sentences. (SHP)

5. Students had difficulty moving the counter along the gameboard properly. (WHP)

6. One student wrote the same three number sentences and counted them as separate answers (eg. 16 = 1 x 16, 1 x 16, 1 x 16). (WHP)

7. No counter was used. (NCD)

Solutions

1. State clearly in directions that **one** die and **one** counter are to be used.

2. Explain **why** the students are to count to 20 (time keeping) and have them practice counting slowly.

3. Explain why a person who rolls 6 begins the game.

4. Stress the use of the "Both-Ways" rule. This lesson offers an excellent opportunity for both the teacher and the students to practice the concept.

5. A whole-group demonstration should be encouraged in order to show the students how to move the counter, take turns, write number sentences, and keep score.

6. The students in general found it extremely hard to do multiplication "backwards" as required in the Multifact game. Perhaps an additional game should be introduced first which involves throwing two dice and multiplying the numbers on top. Each player would then cover the correct answer on the Multifact board with his own counter (perhaps bottle tops with the player's initial written on them). The player with the most squares covered after 10 minutes play wins.

LESSON – 6:22 – Multiplication Revision

Questions

None.

Problems

1. One teacher said he found the matrix multiplication model difficult. (WSP) Two teachers mentioned that the in-service held in Port Moresby helped them to understand the multiplication procedures using base-10 materials. (SHP, NCD)

2. Base-10 materials were not used due to time constraints. (WSP)

3 The students did not finish all the problems. (WSP, NCD)

4. The teachers and students were confused by reference to "rectangle shapes" in the instructions. (SHP)

5. Some students added the blocks at the top of the matrix (multiplicand) to their final answer. (WHP)

6. One teacher instructed the students to use base-10 materials to help them solve their problems, however only about half did so. (NCD)

Solutions

1. Teacher effectiveness in these types of lessons depends primarily on their facility in using the materials. The teachers refer back to the Port Moresby in-service course often.

2. One teacher told the students **not** to work out the problems until they had used the base-10 materials first. This would be a useful suggestion to include in the Teacher's Notes for all lessons which require base-10 materials (eg. "Don't forget to use blocks first!"). (WHP)

3. To reduce the problem of the students adding the second factor (the number across the top) to the final answer (the array inside) leave more space between the base-10 materials and the horizontal line or draw pictures of the two factors instead of using actual base-10 materials.

CONCLUSION

Effective instruction depends to a great extent on how thoroughly the teacher understands the complex relationship between the subject matter concepts, the instructional methodology and the curriculum materials. Consequently it is of primary importance for teachers to work through lessons prior to classroom implementation. Procedures associated with implementing difficult lessons, such as sorting attributes, should be well understood by the teacher before instruction with students commences. The actual manipulation of attribute materials by the teacher as part of their lesson planning will help them anticipate problems the students are likely to encounter and plan their lesson introduction accordingly. Any preliminary in-service training should focus on actually working through the lessons as opposed to a general discussion of teaching methodology and instructional materials.

Classroom Management

Materials Management: In general the teachers in this study exhibited a reasonable grasp of the content and methodology. Problems occurred initially, however, with the organization, management and storage of the curriculum materials. After initial frustrations and delays it was decided that materials such as base-10 blocks, Kina Cards, squared paper and workbooks should be located at the front of the classroom within easy access of both teachers and students. Large manila envelopes served as storage containers for paper materials. Plastic bags or containers would help preserve the degradable items. When storing base-10 blocks, separate containers for each student's set of 1s, 10s and 100s helps ensure that a complete classroom set is available for easy distribution.

In order to reduce the amount of set-up time required, student monitors were effectively utilized to distribute materials. Such a procedure should be recommended in the Teacher's Notes or future curriculum guides. If materials are stored properly and student helpers are responsible for distributing them, more time can be spent on actual lesson activities.

Activity Book: Having access to student activity books seemed fundamental to the success of the trial lessons. Those lessons taught without them often caused confusion. Direct access to activity books allowed students to follow along with the teacher's instructions enabling them to understand lesson objectives and procedures more readily. Teachers found it helpful to be able to refer to specific pictures or diagrams when explaining difficult concepts. At some sites the booklets were stored in the students' desks, at others student monitors distributed them at the beginning of the lesson.

Lesson Organization: In general, successful lessons began with a whole-group demonstration. Such lesson introduction seemed necessary to ensure that the students understood critical procedures prior to breaking up into small groups. This simple technique helped minimize the problem of having to reassemble the whole class in order to clarify basic procedural questions once small groups were working independently.

The organization of small groups initially proved to be difficult for some teachers. Prior to their involvement with the current project, these teachers normally conducted whole-class lessons followed by students completing exercises on an independent basis. The suggested procedure of breaking into four or five groups for half the period or more was not carried out easily.

Suggestions should be made in the Teacher's Notes to help teachers organize groups quickly and efficiently. Successful ways to group students include assigning numbers, drawing cards or choosing sticks. Once this task is accomplished, students are able to quickly begin cooperative group activities. The teacher then moves from group to group answering questions, motivating students and assessing progress. Frequently it is useful to assemble the group at the end of the period to review the day's activities and plan for the next lesson.

Classroom Atmosphere: The teacher plays a prominent role in establishing a positive, relaxed environment in which to learn. In some cases during the trial lessons the teachers were not sensitive to the children's abilities. Particularly when the instructions required children to copy graphics or prepare required manipulative aids.

Occasionally a lesson was not completed because teachers became angry when students were taking too long to prepare the materials. In some cases (particularly in grade two) the tasks were clearly too difficult and time consuming for children of this age. Instead of altering the lesson plan the teachers became cross with the students and themselves. The teachers should not be held totally accountable, however, since one objective of the trialling study was to assess the feasibility of including various types of activities in future curriculum materials. We therefore expected children to experience difficulty with certain lessons.

A word to the teacher about the art of patience and acceptance of student abilities would have been justified here. Though the teacher and student made an impressive effort to construct even the more complicated materials, they all eventually used their better judgement and moved to the next lesson when it was clear that little progress was being made.

Evaluating Student Progress: Finally, with few exceptions, teachers rarely assessed individual student progress on lesson objectives. Appropriate evaluation techniques should be described in the Teacher's Notes to ensure teachers have the means of assessing individual achievement and subsequently make effective instructional decisions. Individuals should be observed during the activity phase of the lesson and exercise books should be carefully checked to be certain students are completing work accurately. Reviewing exercises with the whole class on the chalkboard and evaluating chorused responses is not sufficient to make instructional decisions for even the majority of the class. Careful observation of individual students working in groups, checking exercise books frequently, giving brief tests every week or two and keeping accurate records will go far in improving the teacher's ability to effectively evaluate student progress.

Instructional Materials

Teacher's Notes: Instructions and teaching suggestions should be kept simple and explicit. All pictures used on student activity sheets need to be referenced in the Teacher's Notes. For example, if a hand holding a pencil is displayed on the activity sheet, it should be stated that the picture is there to remind students to use a pencil to write answers in their exericse books. If a picture depicts a student using a measuring device, then it needs to be clearly stated that students are supposed to do the same activity as the child in the picture. The writer should not assume that the teacher will inform the students regarding the significance of the pictures simply because they are displayed.

Background Notes: The rationale for teaching each lesson should be clearly stated at the beginning of each topical series. Include the ultimate goal of the sequence of lessons (eg. length-comparison activities are the first step in developing measurement skills using centimetres and metres). Also list previous skills and concepts which are necessary to effectively carry out the series of activities (eg. students must know how to count to 100, exchange ones and tens and write numbers smaller than 100 in place-value tables before they begin this series of lessons on two-place addition).

If the rationale is not clearly stated, lessons become isolated events and are seen by teacher (and students) as having no real purpose other than perhaps being fun for students. Teachers at times had difficulty seeing reasons for teaching certain lessons in the trial curriculum.

Lesson Introduction: Sample introductions for each lesson should be included. Teachers who were able to devise their own lesson openings had less difficulty implementing the entire lesson. Providing suggestions for introducing the lessons might help the teacher who lacks experience or confidence get off to a better start. For example, when the lesson calls for the students to play a game, a clear explanation of the objective and rules of the game should be suggested in the Teacher's Notes.

Answers: In using these materials, teachers needed confirmation that the answers they reach to problems presented in the lessons are in fact the correct ones. Consequently, all answers to the worksheet exercises and questions presented in the Teacher's Notes should be provided. This gives assurance to teachers who lack confidence and consequently reduces the likelihood that the lesson will be skipped.

Alternative Materials: Often, teachers need access to alternative instructional materials and aids since suggested items are frequently unavailable. Wherever possible the lessons should utilize locally produced materials. Even when centrally produced aids are considered preferable (eg. base-10 materials) locally produced alternatives should be listed in a separate section (eg. seed canoes and rafts or squared paper models).

Such suggestions will ensure that students actually engage in recommended manipulative activities and not skip directly to the symbolic exercises due to the lack of appropriate concrete models. The Teacher's Notes should provide every possible aid to the teacher to ensure that this important concept development stage of the mathematics program is fully implemented.

Review Lessons: To further ensure that skills are being learned and mastered, it would be useful to periodically include a review lesson. A brief assessment test could be administered after these revision exercises to aid teachers in monitoring student abilities and achievement. These tests would also provide a basis for developing and maintaining an accurate record of the pupil's progress.

Teacher In-service: Probably the most important observation made during the implementation of these trial materials involved the preliminary training of the teachers themselves. An important and, in our opinion, vital element associated with the IMP sponsored in-service course held in April 1980 was that the teachers directly experienced the use of the recommended aids in a learning environment similar to that in their own classrooms.

Throughout the study teachers referred back to the Port Moresby In-service during their interviews with the observers. They felt that the new instructional techniques, such as those involving base-10 materials, became clear during the "hands on" approach used throughout the workshops. Similar workshops have subsequently been planned and carried out by project teachers in their own area based on the IMP prototype. In-service experiences of two weeks duration or less can be extremely effective if based on a specific curriculum material that is to be subsequently implemented in the participants' classrooms.

In-service courses that attempt to broaden participants' general background relative to instructional methodology or subject matter competence will have far less impact on teachers' classroom behaviours given a fixed amount of resources and time. Based on our experience, an in-service course designed to assist with the implementation of a specific curriculum product is more effective. Opportunities should be provided for teachers to construct pertinent learning aids to take back to their classrooms. Using the actual instructional materials and aids in a simulated classroom environment should have a considerable effect on teacher classroom behaviours and subsequent student performance.

Appropriate teacher guides and in-service training helped five teachers plan their mathematics lessons more effectively. The availability of student activity books and learning aids helped teachers communicate key mathematics concepts and helped children develop those concepts into practical arithmetic and measurement skills. With less than two weeks in-service training and occasional advice from an on-site observer, the teachers were quite successful overall in co-ordinating various instructional components and constructing reasonably effective lessons.

ACHIEVEMENT TESTS

Grade Level Results: The following three tables show the results of the mathematics and language achievements tests by grade level. PMAT 2, 3 and 4, the Fiji Reading (Sentence Completion) Test and the Dictation exercise are reported. We also include the results of the National Grade Six Examination given to all grade six students in Papua New Guinea in October, 1980. The maths and English results correlate highly with PMAT 4 and Reading (r = .90 maths; r = .88 English). TAS and the Papua New Guinea Reading test are not reported since their results are highly correlated with the results of the corresponding instruments above (PMAT and Fiji Reading).

Table 16

GRADE TWO ACHIEVEMENT (%)

Site	PMAT2	PMAT3	PMAT4	READ	DICT	n_{pmat2}
MP	N/A	N/A	N/A	N/A	N/A	N/A
WSP	24.7	29.2	31.8	N/A	23.0	23
SHP	36.6	43.6	43.9	N/A	N/A	34
WHP	34.5	38.6	40.5	36.3	19.4	19
NCD	25.3	35.3	36.3	53.7	24.9	38
$\bar{x}$	30.1	36.9	38.4	47.3	24.9	29

MP – Manus Province
WSP – West Sepik Province
SHP – Southern Highlands Province
WHP – Western Highlands Province
NCD – National Capital District

Table 17

GRADE FOUR ACHIEVEMENT (%)

Site	PMAT2	PMAT3	PMAT4	READ	DICT	^{n}pmat2
MP	53.5	57.5	55.1	80.9	82.9	22
WSP	48.0	53.3	57.3	70.3	88.3	28
SHP	57.9	63.1	63.6	79.4	86.5	32
WHP	50.5	52.3	55.0	67.2	68.1	42
NCD	53.4	53.4	53.3	80.3	86.4	33
$\bar{x}$	52.6	55.7	56.8	74.9	81.1	31.4

Table 18

GRADE SIX ACHIEVEMENT (%)

Site	PMAT2	PMAT3	PMAT4	READ	DICT	^{n}pmat2
MP	66.0	70.8	72.2	88.7	92.1	30
WSP	55.8	64.6	64.6	80.2	91.0	24
SHP	73.4	74.3	77.8	87.5	90.0	33
WHP	56.0	61.1	63.1	80.9	81.0	25
NCD	66.2	70.0	73.6	91.6	90.8	31
$\bar{x}$	64.3	68.8	71.1	86.4	89.3	28.6

Table 19

CORRELATION OF MEANS FOR NATIONAL EXAMS AND PMAT4 AND READING (%) – GRADE SIX

Site	PMAT4	National MATHS	READ	National ENGLISH
MP	72.2	61.5	88.7	52.5
WHP	64.6	54.0	80.2	33.0
SHP	77.8	73.0	87.5	54.3
WHP	63.1	50.0	80.9	47.3
NCD	73.6	57.3	91.6	59.3
$\bar{x}$	71.1	58.7	86.4	50.0
r	.90		.88	
$\bar{x}_{nat}$	N/A	51.3	N/A	44.4

Table 20 shows the means by grade level and standard deviation for the five achievement measures.

Table 20

ACHIEVEMENT BY GRADE (%)

Grade	PMAT2	PMAT3	PMAT4	READ	DICT	^{n}pmat2
2	30.1	36.9	38.4	47.3	24.9	114
4	52.6	55.7	56.8	74.9	81.1	157
6	64.3	68.8	71.1	86.4	89.3	143
$\bar{x}$	50.4	54.6	56.9	75.3	72.8	138
SD	17.2	16.0	16.5	19.5	27.9	

As expected, scores increase with grade though not in equal increments. For each measure the scores increase between grade two and four on an average of two times that between grades four and six. This uneven growth could be an artifact of the assessment instruments or a reflection of significant increases in learning during this period, perhaps due to the development of English fluency during approximately the same period. There was a tendency for the ratio of growth between grade levels (two to four and four to six) to diminish as the study progressed. Table 21 below shows the decreasing ratio between change in growth rate for grade two and four versus that for grade four and six. This result indicates more consistent learning growth across grades from July to October.

Table 21

PMAT	Ratio Between Levels
2	1.92 (July)
3	1.44 (August)
4	1.29 (October)

It is interesting to note as well that mathematics achievement across time (PMAT 2, 3 and 4) also increased though again not consistently. The change between the pre- and post-test measures are about two times that of the post- and retention results. (4.2 vs 2.3). This observation will be discussed in greater detail in a later section.

School Results: Table 22 summarizes achievement means by school. Since the Manus site had no grade two, we report only the results for grades four and six to facilitate comparison.

Table 22

POOLED GRADE FOUR AND SIX AVERAGE ACHIEVEMENT BY SCHOOL (%)

Site	PMAT2	PMAT3	PMAT4	READ	DICT	n_{pmat2}
MP	60.7	65.1	64.6	85.3	88.0	52
WSP	51.9	59.0	61.0	75.3	89.7	52
SHP	65.7	68.7	70.7	83.5	88.3	65
WHP	53.3	56.7	59.1	74.1	74.6	67
NCD	59.8	61.7	63.5	86.0	86.6	64
$\bar{x}$	58.3	62.4	63.8	80.8	85.4	60

The PMAT 2, 3 and 4, Reading and Dictation results for grades four and six were each submitted to a two-way analysis of variance to test significant main effects relative to grade level and school site. Table 23 shows the results of the analysis for PMAT 2 (summary tables are similar for the other four variables). Except for PMAT 4 the two-way interaction for each AVOVA was not significant ($p > .05$). Therefore we can safely interpret the significance of the grade and school main effects.

Table 23

TWO-WAY ANOVA FOR PMAT2
GRADES FOUR AND SIX

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main effects	16764.0	5	3352.8	39.6	0.000
Grade	9319.5	1	9319.5	110.1	0.000
School	5844.1	4	1461.0	17.3	0.000
2-way interactions					
Grade x School	750.3	4	187.6	2.2	0.068
Explained	17514.3	9	1946.0	23.0	0.000
Residual	21678.1	256	84.7		
Total	39192.5	265	147.9		

With the possible exception of PMAT 4 all measures of achievement, as expected, are significantly different across grade levels. In other words the grade six students' level of achievement was significantly higher than that of grade four students. We are fairly safe then in assuming that significant growth takes place in the last two years of community school. Since there was no grade two at one site, we didn't test the grade two/four contrast though we suspect even greater growth during this period due to larger mean differences between grades two and four compared to grades four and six. The analysis also clearly indicates a significant difference in level of achievement across the five sites, at least in grades four and six. To test where the differences occured achievement scores from each grade level (two, four and six) were submitted to one-way analysis of variance.

If a significant difference was found between sites for a given grade level, the Student-Newman-Keuls a posteriori procedure was employed in order to determine homogeneous subsets. The S-N-K procedure divides the five sites into two or more subgroups, the members of which can not be distinguished from one another. For each grade level, two or sometimes three subgroups were determined for each achievement measure PMAT 2 and 3, READING, DICTATION.

It should be remembered that it is inappropriate to generalize the results of a single school to all schools in the province in order to attempt comparisons between regions. There may be as much variance in achievement within the province as between provinces. To our knowledge no reliable comparative data is currently accessible to assist with such an evaluation, though as the national testing program expands this situation may change rapidly.

The significant differences ($p < .001$ for all contrasts) found between sites followed a consistent pattern for PMAT 2 and 3. Table 24 summarizes the results of the S-N-K a posteriori procedure. The heavy lines divide the five sites into homogeneous subgroups. For example, for grade four SHP, MP and NCD exhibited significantly higher PMAT2 scores than did WHP and WSP. PMAT3 offered a similar pattern of results. SHP, MP and NCD consistently outperformed WHP and WSP relative to mathematics achievement.

Table 24

HOMOGENEOUS SUBGROUPS OF SITES*
PMAT2

Rank	Grade 2	4	6
1	SHP	SHP	SHP
2	sd WHP	MP	NCD
3	NCD	NCD	MP
4	WSP	WHP	WHP
5	N/A	WSP	WSP

*S-N-K a posteriori procedure
No grade 2 at MP
sd = significant difference

Similar ANOVA analysis showed significant differences ($p < .001$ for all contrasts) in READING and DICTATION achievement between sites. The results for grade two are incomplete due to difficulties encountered with data collection.

Again, S-N-K a posteriori procedures were carried out for each significant ANOVA. The results are given in tables 25 and 26 below. Again SHP, MP and NCD outperformed the other two sites in READING achievement. With DICTATION, however, WSP exhibited a very strong performance in contrast to its relative position on all other measures.

Table 25

HOMOGENEOUS SUBGROUPS OF SITES*
READING

Rank	Grade 2	4	6
1	sd NCD	MP	NCD
2	WSP	NCD	MP
3	N/A	SHP	SHP
4	N/A	WSP	WHP
5	N/A	WHP	WSP

* S-N-K a posteriori procedure
N/A = Missing data
sd = Significant data

Table 26

HOMOGENEOUS SUBGROUPS OF SITES*
DICTATION

Rank	Grade 2	4	6
1	NCD	WSP	MP
2	WSP	SHP	WSP
3	sd WHP	NCD	NCD
4	N/A	MP	SHP
5	N/A	WHP	WHP

* S-N-K a posteriori procedure
N/A = Missing data
sd = Significant differences

In addition to the five community school sites we gave PMAT4 and the Reading test to grades two, four and six at an International School in Port Moresby. The student population consisted primarily of expatriate children from a wide range of cultural backgrounds. Approximately 15% of the student population were Papua New Guineans. The tests were administered during the same period as for the five project sites.

Also two of the project classroom observers (Johnson and Rowe) administered PMAT2 to children in grades three and five at a school in Oceanside, California, United States of America. The school population is made up primarily of children from working class and military families. This version of PMAT was selected since the testing period (February) was planned for five months after the start of the school year in the United States, (September) coinciding with a similar period prior to the administration of the PMAT2 in Papua New Guinea (February through June).

These results are presented only to assist the reader in assessing the difficulty level of the tests involved and are not intended to be used as a means for comparison of achievement between sites. Teacher qualifications, instructional methods and availability of materials vary enormously across the three populations making comparisons of achievement scores meaningless when taken out of environmental context.

The results are presented for grades three and five for the United States and International school sites since these students all attended one year of kindergarden (U.S.) or preparatory (International) school prior to grade one. The results for the International school site were computed from grade two, four and six data, using the linear regression estimator technique. All subjects had schooling for three years, five months and five years, five months for PMAT2, and three years, eight months and five years, eight months for PMAT4 and Reading.

Table 27

ACHIEVEMENT SCORES FOR P.N.G., INTERNATIONAL AND U.S. SCHOOLS (%)
PMAT2, PMAT4 AND READING

Years of Schooling	PMAT2[4]		PMAT4[5]		READING[5]	
	U.S[1]	P.N.G.[2]	INT[3]	P.N.G	INT	P.N.G.
4	59.9	52.6	61.3	56.8	94.4	74.9
6	78.1	64.3	77.7	71.1	98.5	86.4
$\bar{X}$	69.0	58.5	69.5	64.0	96.5	80.7

1. U.S. = United States site – grade 3 and 5 plus one year kindergarden.
2. P.N.G. = Community School sites – grade 4 and 6.
3. INT = International site – grade 3 and 5 (linear estimate from grade 2, 4 and 6 data) plus one year preparatory.
4. PMAT2 administered five months after start of school for P.N.G. and U.S. subjects.
5. PMAT4 and READING was administered eight months after the start of school year for P.N.G. and International subjects.

The range of scores afforded by PMAT 2 and 3 indicate that none of the groups means were hampered by a ceiling effect while it is clear that this is not the case with READING means for International School subjects. Overall the results are somewhat more encouraging than previous studies have indicated, at least with regard to mathematics achievement.

Pre-, Post- and Retention Test Contrasts: The following table shows achievement means for the four paired experimental and control groups. Only four sites afforded an experimental/control pair.

Table 28

CONTROL AND PAIRED EXPERIMENTAL GROUP ACHIEVEMENT MEANS (%)
PMAT 2, 3 AND 4

Site	Grade	PMAT2	n	PMAT3	n	PMAT4	n
WSP	2E	24.7	23	29.3	26	31.8	22
	2C	28.5	23	31.4	27	31.1	29
SHP	2E	36.6	34	43.6	34	43.9	32
	2C	30.7	36	37.1	36	39.9	36
NCD	4E	53.4	33	53.4	34	53.3	31
	4C	51.2	35	57.2	34	55.3	29
WHP	6E	56.0	25	61.1	24	63.1	22
	6C	57.5	24	62.0	19	64.1	29
	$\bar{X}$ E	43.3	29	46.8	30	48.1	27
	$\bar{X}$ C	41.8	30	45.7	29	47.6	31

E = Paired experimental
C = Control
n = Number of subjects

In order to analyze achievement gains over the trialling and retention periods, two new variables were defined as follows:

1. DELTA 32 = PMAT3 – PMAT2
2. DELTA 43 = PMAT4 – PMAT3

DELTA 32 computes the change in pre- and post- test achievement scores (PMAT 2 and 3) in order to measure change during the trialling period and similarly DELTA 43 computes the change between the PMAT 3 and 4. Table 29 shows DELTA 32 and DELTA 43 by grade.

Table 29

DELTA 32 AND DELTA 43 BY GRADE

Grade	DELTA 32	DELTA 43
2	7.8	0.9
4	3.1	1.0
6	3.7	2.5
$\bar{X}$	4.6	1.6

These results suggest the grade two subjects exhibited greater gain during the trialling period than grades four and six. To test the significance of this result a new variable was defined which computed the change in achievement between the trialling and retention periods (DELTAGR = DELTA 32 – DELTA 43). An ANOVA computed for DELTAGR indicated a significant difference ($F = 9.4$; $p < .001$) between grade levels for changes in growth rates. The subsequent Student-Newman-Keuls procedure indicated significantly greater gains for grade two over grades four and six.

Table 30 below shows the results of a t-Test computed between DELTA 32 and DELTA 43 across the total population ($n = 369$). The results indicate that achievement gains during the retention period diminished significantly over those of the trialling period ($t = 5.1$, $p < .001$).

Table 30

T-TEST BETWEEN DELTA 32 AND DELTA 43

Variable	Number of Cases	Mean	Standard Deviation	Standard Error	*(Differences) Mean	Standard Deviation	Standard Error	T Value	Degrees of Freedom	2-Tail Probability
DELTA 32	369	4.6	7.4	0.4	3.0	11.4	0.6	5.1	368	0.000
DELTA 43		1.6	6.3	0.3						

The change in achievement scores for the control groups and paired experimental groups are presented in Table 31 below.

Table 31

DELTA 32 AND DELTA 43 FOR CONTROL AND PAIRED EXPERIMENTAL GROUPS

Site	Grade	Control		Paired Experimental	
		DELTA 32	DELTA 43	DELTA 32	DELTA 43
WSP	2	3.8	3.3	4.6	3.7
SHP	2	6.4	2.8	7.6	0.3
•NCD	4	5.7	−1.0	−0.7	0.2
WHP	6	3.9	2.8	5.1	1.5
	$\overline{X}$	5.2	1.9	4.0	1.2

At three of the four sites the experimental groups outperformed the paired control groups. Caution should be exercised in drawing any firm conclusions from this result in that little documentation is available on what actually went on in the control classes. We are unable to assess to what extent the experiences in these classrooms were comparable to those of the paired experimental groups. Also the grade four NCD experimental group experienced a slightly negative growth curve during the trialling period and the control group experienced negative growth during the retention period. Since these results ran counter to our experience at all the other sites we feel the prudent course of action is to drop this group from consideration. Table 32 shows the results when only the grade two and six control and paired experimental groups are included.

Table 32

DELTA 32 AND DELTA 43 FOR CONTROL AND PAIRED EXPERIMENTAL GROUPS – GRADES TWO AND SIX

Site	Grade	Control		Paired Experimental	
		DELTA 32	DELTA 43	DELTA 32	DELTA 43
WSP	2	3.8	3.3	4.6	3.7
SHP	2	6.4	2.8	7.6	0.3
WHP	6	3.9	2.8	5.1	1.5
	$\bar{X}$	5.0	3.0	6.0	1.6

The paired experimental groups experienced slightly greater gains during the trialling period than the control groups and slightly less gain during the retention period. Because of poor matching of groups and lack of random assignment of subjects, no conclusion will be drawn regarding contrasts between these paired groups.

Item Analysis: Frequency distributions were computed for each item in PMAT 2 and 3. The items were grouped by the major content strands:

1. Measurement
2. Number Operations
3. Mathematical Language
4. Problem Solving Applications

Table 33 shows the topic composition of the 62 exercises (55 test items) for PMAT 2 and 3.

Table 33

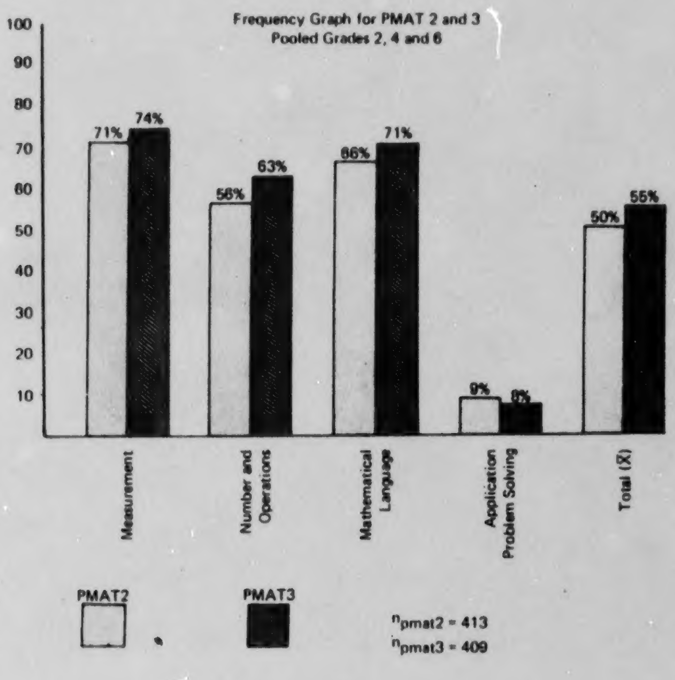
ITEM COMPOSITION FOR PMAT 2 AND 3

Topic	Exercise	Total
Measurement	1, 2, 13, 20, 21, 22, 31, 32, 38, 39, 46	11
Number and Operations	5, 6a, 6b, 6c, 7a, 7b, 8, 9, 10, 11, 14, 15, 16, 17, 18, 23, 24, 25a, 25b, 25c, 26, 27, 28, 29, 33, 34, 35, 36, 37, 41, 42, 43, 49, 50, 51, 52	36
Mathematical Language	3, 4, 12, 19, 30, 44, 45	7
Application Problem Solving	40, 47, 48, 53a, 53b, 54a, 54b, 55	8
	Total	62

Note: Each Test consisted of 55 items with a total of 62 exercises.

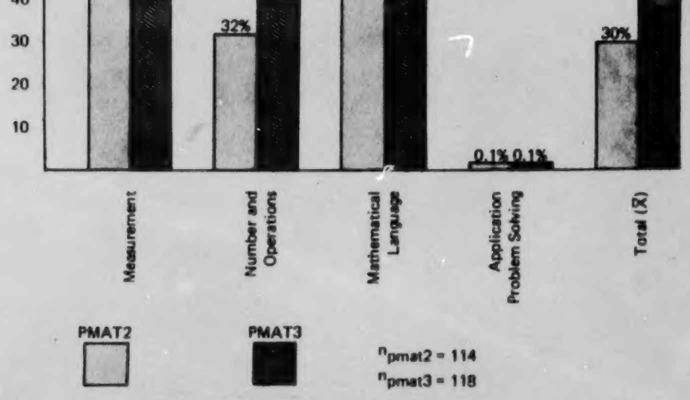
Graphs of the percent of correct responses broken down by the four strands (Measurement, Number and Operations, Mathematical Language and Problem Solving Applications) are presented in Figures 32 to 35. The average results for the total test are given as well.

Figure 32



Frequency Graph for PMAT 2 and 3
Pooled Grades 2, 4 and 6

Figure 33



Frequency Graph for PMAT 2 and 3
Grade 2

Figure 34

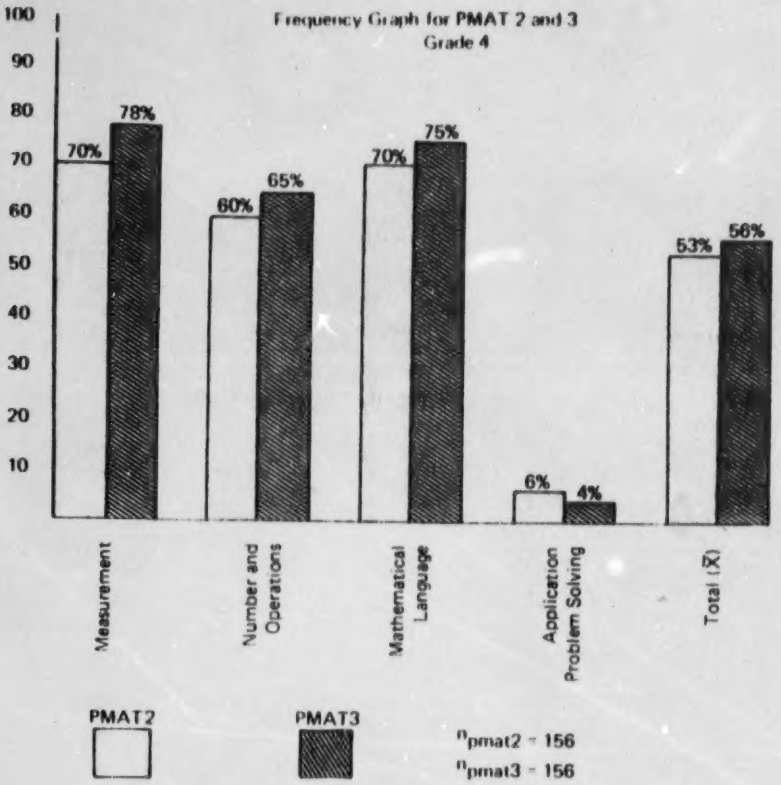
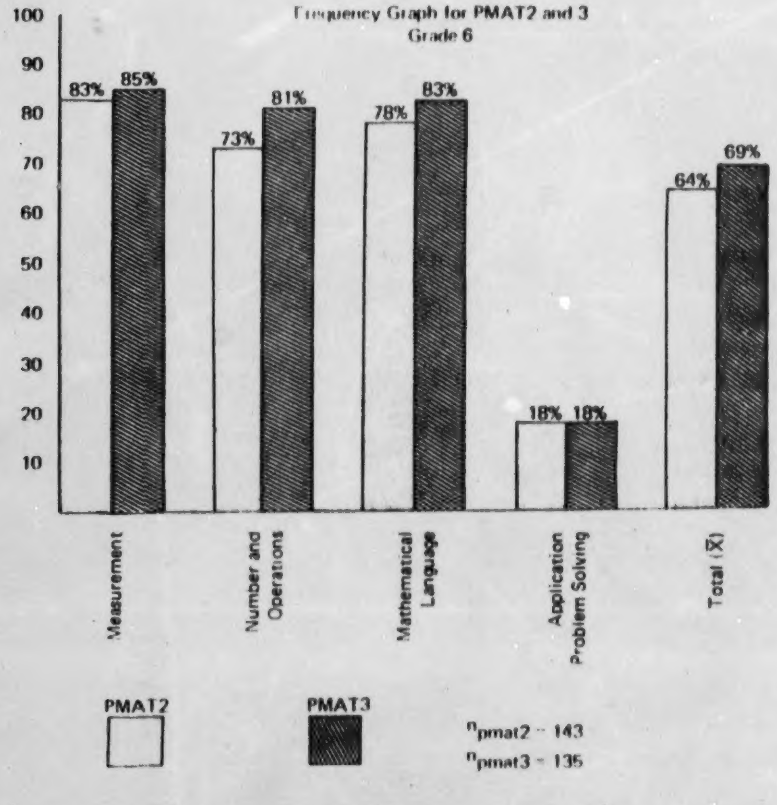


Figure 35



Overall the percent change is roughly 5% for measurement, Number and Operations and Mathematical Language, while no growth in Problem Solving Applications was apparent from this sample of exercises.

It is particularly instructive to compute achievement relative to grade level expectations. Table 34 lists test items groupd by grade level objectives.

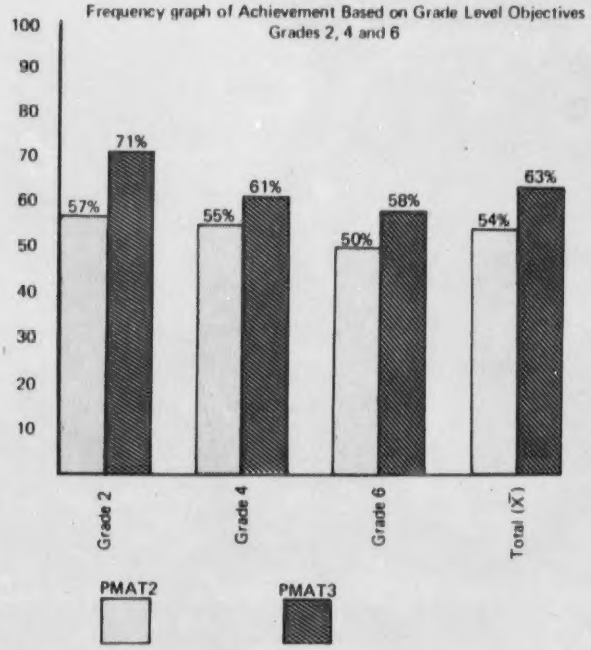
Table 34

PMAT ITEMS GROUPED BY GRADE LEVEL OBJECTIVES

Grade	Items	Total Items
2	1, 2, 3, 4, 5, 6a, 6b, 6c, 7a, 7b, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25a, 27, 28, 29, 30, 31	33
4	17, 18, 19, 20, 21, 22, 23, 24, 25a, 25b, 25c, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 44, 45, 46	31
6	23, 24, 25a, 25b, 25c, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53a, 53b, 54a, 54b, 55	37

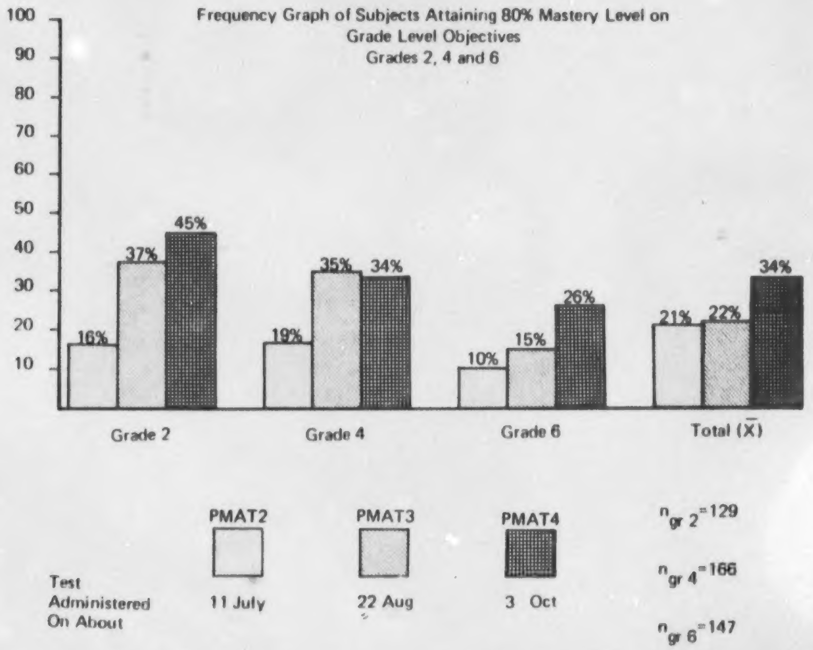
The graph in figure 36 below shows average achievement on grade level objectives for grades two, four and six and the mean across all grades.

Figure 36


Frequency graph of Achievement Based on Grade Level Objectives
Grades 2, 4 and 6

We interpret the above graph to mean that, pooled across all subjects, achievement on appropriate grade level objectives was about 54% prior to the trialling period (PMAT2) and 63% after implementation (PMAT3). Average achievement diminishes across grades with grade two showing the highest level of relative achievement (57%–PMAT2 and 71% PMAT3), with grade four next (55%–PMAT2 and 61%–PMAT3) and grade six showing the lowest level (50%–PMAT2 and 58%–PMAT3). Grade two also showed the greatest gain (14%) compared to grade four (6%) and grade six (8%).

Figure 37


Frequency Graph of Subjects Attaining 80% Mastery Level on Grade Level Objectives Grades 2, 4 and 6

The graph in Figure 37 above shows the percent of children attaining an arbitrary mastery level of 80% on grade level objectives. Results are presented for PMAT 2, 3 and 4. The percent of the students attaining grade level expectations diminishes from grade two to grade six, but consistently increases over the three testing periods (11 July, 22 August, 3 October). In Table 35 below additional data necessary for computing grade level mastery scores are presented.

Table 35

MASTERY LEVEL ATTAINMENT (⩾ 80%) – PMAT 2, 3 AND 4

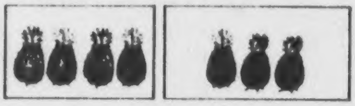
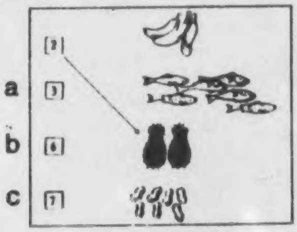
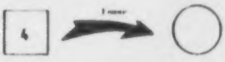
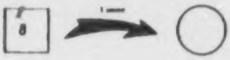
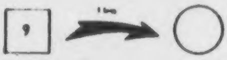
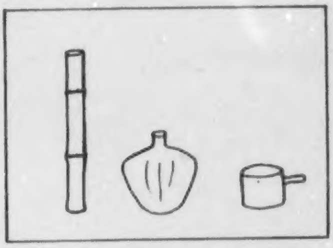
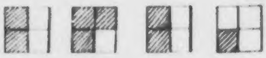
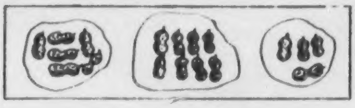
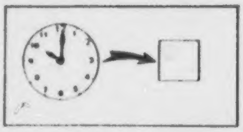
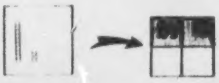
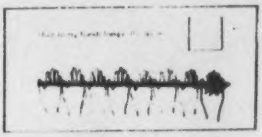
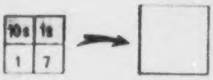
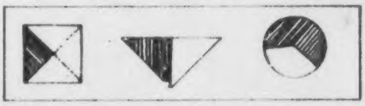
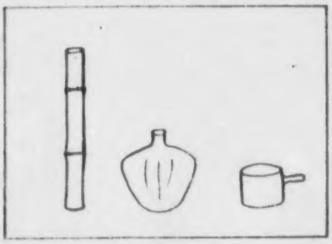
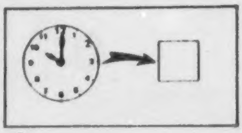
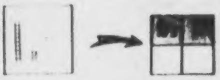
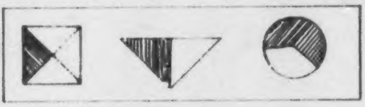
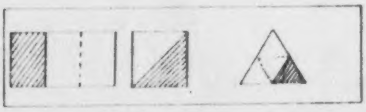
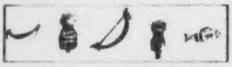
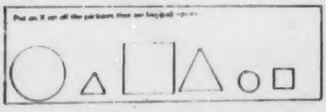
Grade Level	Grade Level Max. Raw Score	Expected Score (80% Mastery)		% Subjects ⩾ 80% Mastery		
		Raw	% of Max.	PMAT2	PMAT3	PMAT4
2	33	26.4	39	16	37	45
4	50	40.0	60	19	35	34
6	67	53.6	80	10	15	26
$\bar{X}_A$	52	41.5	63	21	22	34

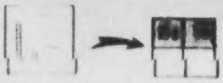
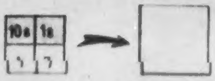
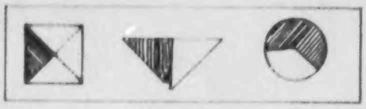
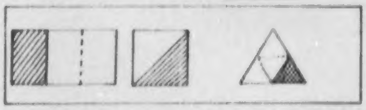
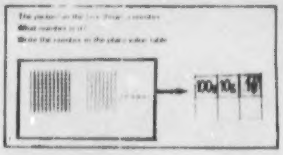
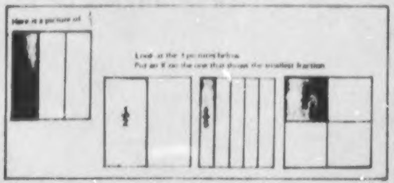
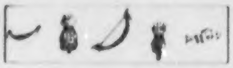
$\bar{X}_A$ = Total mean adjusted for unequal cells.

Two additional lines of analysis were carried out involving the identification of test items which generated higher than average gains in each grade as well as items which students found particularly difficult. Table 36 presents the items which generated gains exceeding the average gain for the entire grade level. Reviewing objectives associated with these items should offer insight into which learning aims were most positively effected by the instruction. The table is organized by grade level with the mean achievement gain for each grade given in column two. We reproduced each test item (PMAT3) for the convenience of the reader.

Table 36

ITEMS GENERATING ACHIEVEMENT GAINS GREATER THAN MEAN GRADE LEVEL GAINS (PMAT 2 AND 3)

Grade ($\Delta\bar{X}$)	PMAT3 Items ($\Delta\bar{X}$ Item > $\Delta\bar{X}$ Grade)
2 (14%)	5  6c  8  9  10 11  20  12  14  21  23  31  24  28 
4 (6%)	20  21  23  25 a 1 5 + 7 26 Subtract. 3 4 − 1 7 28  29  30  35 Multiply 8 × 5 37 How many 4's in 12? (Divide) 4)12 44 

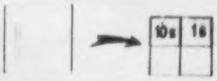
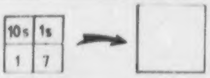
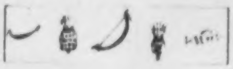
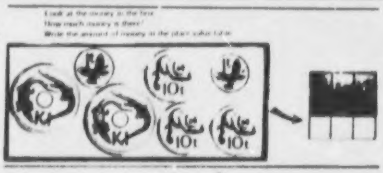
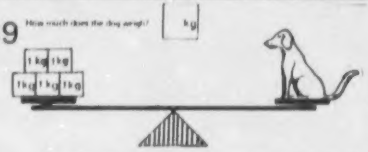
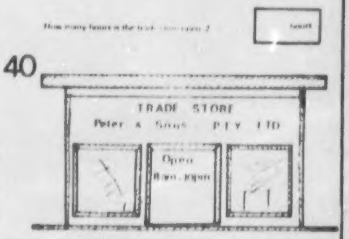
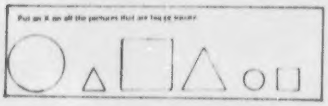
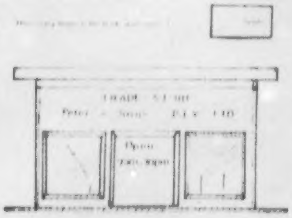
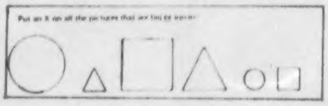
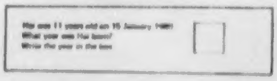
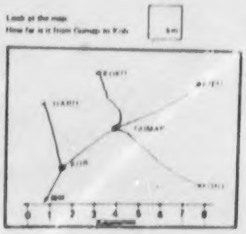
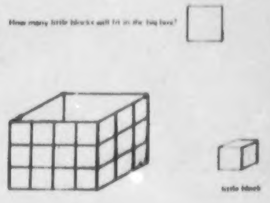
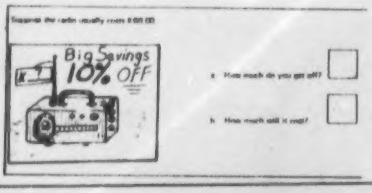
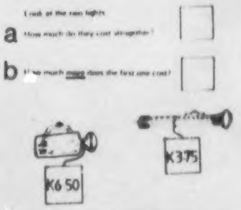
6 (8%)	23  24  25c 2 7 3 + 1 6 6 26 Subtract 3 4 − 1 7 28  29  33  41  30  42 Multiply × 4 51 Divide 8)96 52 Divide 13)338

$\Delta\overline{X}_{Grade}$ = Mean grade level gain.
$\Delta\overline{X}_{Item}$ = Mean Item gain.

Finally Table 37 presents items from PMAT3 which less than 30% of the subjects in each grade level successfully answered. To avoid confusion we included only items that correspond to grade level objectives.

Table 37

ITEMS CORRECTLY ANSWERED BY LESS THAN 30% OF THE SUBJECTS (PMAT3)

Grade	PMAT3 Items
2	23  24  25a 1 5 + 7 30 
4	34  39  40  42 Multiply 2 7 × 4 45 
6	42  45  47  50 Divide 3)80 48  49 Multiply 1 5 4 × 2 3 52 Divide 13)338 55  53a  54b 

Ten of the fourteen items on which the grade two subjects exhibited mean achievement gains greater than 14% involved number and operations:

1. Whole Number – 7 items
2. Place-value – 2 items
3. Fraction – 1 item

Of the remaining four items, three involved measurement concepts (volume, time and length) and one mathematical language ("sameness").

Grade four results offered a similar pattern. Of the eleven items offering gains greater than 6%, seven involved number and operations:

1. Number Operations – 3 items
2. Place-value – 2 items
3. Fraction – 2 items

Measurement accounted for two items (volume and time) and mathematical language two ("all", "and").

Similarly for **grade six**, eleven of the twelve items on which gains of more than 8% were computed involved number and operations:

1. Number Operations – 5 items
2. Place-value – 3 items
3. Fraction – 3 items

The remaining item was related to mathematical language ("all").

The most difficult items (those with less than a 30% success rate) overlapped little with items affording high gains. For grade two and four, place-value items 23, 24 and 34 fell into both categories indicating that though these problems were difficult, substantial progress was made by several children. The overall achievement means remain far too low, however, for such a basic concept. Regarding Mathematical Language, "all" caused the most difficulty for grade two subjects and the disjunctive (inclusive) connective "or" for grades four and six. Harder computation exercises were missed by more than 30% of the children in each grade level and only once (three digit by two digit division in grade six) did a low success rate (< 30%) exercise fall into the high achievement gain category (> 6% gain in this case). We interpret this to mean that hard problems remain hard, though progress can be made through instruction leading to greater understanding followed by sufficient practice and application.

The most significant finding relates to the overall poor performance on Problem Solving Application items. All but one problem solving exercise fell into the under 30% success rate category with several exhibiting less than a 6% success rate (item 40 for grade four, items 53a, 53b and 55 for grade six). Note that grade four was assigned only one problem solving item (item 40) as a grade level objective. Grade six was assigned all eight problem solving exercises. No application items fell into the high achievement gain category. This analysis supports the results presented in the content-strand-graphs included in the previous section. Clearly though some progress was made in other strands of the mathematics curriculum, no significant improvement in the ability to apply language, measurement and computation skills in solving mathematical story problems was apparent.

COGNITIVE ASSESSMENT

Cognitive Tasks: Results from the cognitive assessment clinical interviews are presented in Table 38 below. The range of each variable is given followed by means organized by school and grade. In order to facilitate comparisons between schools, the overall average of the grade two means were used to adjust the MP total school results for each variable.

Table 38

COGNITIVE TASK MEANS
SITE BY GRADE

Site	Grade	Age	Sex (% girls)	VM1 (12)	VM2 (12)	MS (7)	CN (2)	CL (2)	DS (19)	LC (3)	CI (3)	PMAT2 (%)	PMAT3 (%)	PMAT4 (%)	READ (%)	DICT (%)	n
MP	*$\bar{X}$	11.3	40.0	7.8	7.0	2.4	1.5	0.7	16.6	2.4	2.1	50.9	55.9	56.0	72.3	68.1	27
	2^t	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	4	11.1	8.3	8.0	7.3	2.4	1.8	0.7	17.1	2.5	2.6	54.6	58.3	56.6	82.4	85.4	12
	6	13.5	46.7	9.0	7.1	2.8	1.9	1.0	17.9	2.8	2.4	68.1	72.2	72.4	89.2	92.5	15
WSP	$\bar{X}$	12.2	31.7	6.7	6.5	1.9	0.7	0.6	15.0	1.9	1.5	42.3	47.4	50.7	*63.6	67.7	41
	2^t	11.1	42.9	6.1	5.2	1.4	0.4	0.4	11.9	1.6	1.3	25.7	30.5	33.1	N/A	21.1	14
	4	11.6	16.7	7.0	7.1	2.1	0.8	0.6	10.2	2.2.	1.3	47.1	53.0	57.1	70.8	88.3	18
	6	15.0	44.4	6.9	7.3	2.1	1.0	0.9	17.4	1.8	2.1	56.7	62.1	62.1	79.0	90.8	9
SHP	$\bar{X}$	11.6	40.0	8.8	8.9	2.6	1.5	0.8	18.6	2.5	1.9	56.4	61.2	64.1	*72.1	*68.4	45
	2^t	9.2	46.7	7.8	8.2	2.2	1.0	0.4	18.6	2.2	1.5	36.1	42.5	43.2	N/A	N/A	15
	4	11.3	40.0	9.5	9.9	2.5	1.7	0.7	18.5	2.5	1.7	57.8	64.0	65.2	78.5	84.4	15
	6	14.3	33.3	9.2	8.6	2.9	1.9	1.4	18.8	2.9	2.5	75.1	77.2	81.2	90.6	91.1	15
WHP	$\bar{X}$	10.8	39.5	7.0	8.1	2.4	1.1	0.4	17.5	2.4	1.7	48.1	49.9	52.5	61.1	57.1	43
	2^t	7.5	38.5	6.1	7.1	2.3	0.7	0.4	15.9	2.2	1.4	31.1	36.2	38.7	34.3	17.0	13
	4	11.4	40.0	6.4	7.6	2.5	0.8	0.3	18.0	2.1	1.7	50.6	52.1	54.0	65.8	66.7	15
	6	12.5	40.0	8.4	9.5	2.4	1.6	0.5	18.3	2.9	1.9	56.8	60.3	62.6	78.9	81.0	15
NCD	$\bar{X}$	10.5	60.0	5.4	6.6	2.1	1.5	1.0	14.3	2.1	2.0	48.9	55.0	56.8	74.2	67.6	45
	2^t	8.5	53.3	5.8	6.6	1.7	1.1	0.7	12.6	1.5	1.4	25.5	37.1	32.6	51.4	29.1	15
	4	10.7	66.7	4.7	5.7	2.0	1.5	1.1	16.4	2.3	2.1	54.8	57.6	57.6	82.3	86.8	15
	6	12.3	60.0	5.6	7.5	2.5	1.7	1.3	14.0	2.4	2.3	66.4	71.5	74.0	88.0	86.9	15
Grand *$\bar{X}$		11.4	41.2	7.2	7.5	2.3	1.3	0.7	16.5	2.3	1.9	50.9	55.4	57.5	68.8	65.7	201

* Adjusted for missing data

$\bar{X}_t$ = mean total subjects at site.

$\underset{(12)}{\text{VM1}}$ = variable range (0, 12).

Table 39 summarizes the same results by grade level.

Table 39

POOLED COGNITIVE TASK MEANS
GRADE TWO, FOUR AND SIX

Grade	Age	Sex (% girls)	VM1 (12)	VM2 (12)	MS (7)	CN (2)	CL (2)	DS (19)	LC (3)	CI (3)	PMAT2 (%)	PMAT3 (%)	PMAT4 (%)	READ (%)	DICT (%)
2	9.2	45.6	6.5	6.8	1.9	0.8	0.5	14.8	1.9	1.4	29.6	36.8	38.2	41.9	22.8
4	11.2	34.7	7.1	7.5	2.3	1.3	0.6	17.2	2.3	1.8	52.7	56.9	58.2	75.5	82.2
6	13.4	44.9	7.9	8.1	2.6	1.7	1.0	17.3	2.6	2.2	65.3	69.4	71.3	85.8	88.4
$\bar{X}$	11.4	41.3	7.2	7.5	2.3	1.3	0.7	16.5	2.3	1.9	50.9	55.4	57.5	*68.8	*65.7

* Adjusted to account for missing grade 2 data.

In order to facilitate analysis of these results, a new variable (COGTOT) was defined. Since all the cognitive measures correlated positively it was possible to construct a continuous variable by summing the nominal results of five classification and conservation tasks – conservation of number, conservation of length, logical classification, class inclusion and double seriation (converted to a nominal 0–2 scale). COGTOT has a range of 0 to 12 and is defined as follows:

$$\text{COGTOT} = \text{CN} + \text{CL} + \text{LC} + \text{CI} + \text{DS}$$

COGTOT is interpreted here as a general measure of developmental competence. Justification for such a procedure is found in Mpiangu and Gentile (1975), and Englehardt and Weibe (1980). Three measures of memory (visual memory: VM1 – objects; VM2 – symbols; and memory space – MS), two language measures (Fiji sentence completion – READ 1 and dictation – DICT), one mathematics achievement score (PMAT2) and a measure of achievement growth (DELTA32 = PMAT3 – PMAT2) constitute the set of variables considered in this section. Table 40 summarizes the COGTOT means along with other memory and achievement measures by site, grade level and sex.

Table 40

COGTOT AND OTHER SELECTED MEASURES
BY SITE, LEVEL AND SEX ($\overline{X}$%)

Site/level/sex	COGTOT (%)	VM1 (%)	VM2 (%)	MS (%)	READ (%)	DICT (%)	PMAT2 (%)	DELTA32 (%)
MP*	68.1	65.3	59.0	33.8	72,3	66,1	50.9	5.0
WSP	47.4	55.5	54.3	26.6	*63.6	67.7	42.3	5.1
SHP	71.9	73.7	74.3	36.5	*72.1	*68.4	56.4	4.8
WHP	59.5	58.3	67.6	34.7	61.1	57.1	48.1	1.8
NCD	60.4	44.8	54.8	29.8	74.2	67.6	48.9	6.1
2 (all)	46.6	53.8	56.6	27.2	41.9	22.8	29.6	7.2
4 (all)	62.6	59.1	62.7	33.0	75.5	82.2	52.7	4.2
6 (all)	76.0	65.8	67.3	36.9	85.8	88.4	65.3	4.1
Male	64.6	59.0	61.9	33.6	73.1	73.8	52.7	4.2
Female	59.8	61.2	63.4	31.4	75.8	69.2	48.3	4.8
$\overline{X}$* Total	62.7	59.9	62.5	32.7	68.8	65.7	50.9	4.5

* Adjusted for missing data.
n = 201

In order to better understand the relationships between memory, cognitive language and mathematics measures, a correlation coefficient matrix was computed between all achievement and cognitive variables for the total population (n = 201). The results are given in table 41.

Table 41

CORRELATION COEFFICIENT MATRIX (r)*
ALL COGNITIVE AND ACHIEVEMENT MEASURES

Variable	COGTOT	VM1	VM2	MS	READ	DICT	PMAT2	DELTA32
COGTOT	1.00	0.32	0.12	0.30	0.52	0.49	0.63	¯ .07
VM1	0.32	1.00	0.36	0.30	0.27	0.33	0.28	¯0.08
VM2	0.12	0.36	1.00	0.25	0.06	0.18	0.22	¯0.04
MS	0.30	0.30	0.25	1.00	0.33	0.35	0.42	¯0.10
READ	0.52	0.27	0.06	0.33	1.00	0.82	0.77	¯0.23
DICT	0.52	0.33	0.18	0.35	0.82	1.00	0.80	¯0.30
PMAT2	0.63	0.28	0.22	0.42	0.77	0.80	1.00	¯0.49
DELTA32	¯ .07	¯0.08	¯0.04	¯0.10	¯0.23	¯0.30	¯0.49	1.00

*r = Pearson-product-moment correlation.
n = 201

The correlation between COGTOT and PMAT2 is r = 0.63 indicating that this general cognitive measure accounts for 40% of the variance in mathematics achievement. Likewise COGTOT accounts for only 27% (r = 0.52) of the variance associated with the language achievement (READ and DICT). READ is even more highly correlated with PMAT2 (r = 0.77) as is DICT (r = 0.82) accounting for 58% and 67% of the variance in mathematics achievement respectively. Smaller though still significant correlations were found between the memory measures and mathematics achievement. Clearly language competence is contributing in important ways to the level of mathematics achievement experienced by this group of students. Cognitive development is also predictive of mathematics achievement though not to the same extent as language.

All measures correlate negatively with achievement growth (DELTA 32). Children who exhibited superior language, memory, cognitive and mathematics skills on the pre-test (PMAT2) experienced a smaller gain in achievement than those with poorer skills. This phenomenon can be accounted for by realizing that children with lower scores on the criteria referenced pre-test missed some of the easier problems the higher-scoring children got correct. On the post-test, children who scored lower initially would be confronted with relatively easy, previously missed, items and should therefore tend to show greater percentage gains. A carefully norm-referenced test where items are given weighted values would minimize this bias.

To further explore the relationships between these variables table 42 shows the correlations between PMAT2 and the cognitive, memory and language variables broken down by site, grade level and sex.

Table 42

CORRELATION (r) OF PMAT2 WITH COGTOT, VM1, VM2, MS, READ AND DICT

Site/level/sex	COGOT (r)	VM1 (r)	VM2 (r)	MS (r)	READ (r)	DICT (r)	PMAT2 ($\bar{X}$%)
MP	0.52	0.03	0.17	0.32	0.59	0.53	50.9*
WSP	0.61	0.16	0.29	0.35	0.73	0.81	42.3
SHP	0.59	0.36	0.04	0.27	0.62	0.51	56.4
WHP	0.42	0.33	0.22	0.29	0.78	0.78	48.1
NCD	0.58	0.03	0.19	0.53	0.77	0.90	48.9
2 (all)	0.38	0.33	0.24	0.25	0.26	0.32	29.6
4 (all)	0.39	0.10	0.15	0.09	0.60	0.37	52.7
6 (all)	0.61	0.25	0.05	0.45	0.58	0.53	65.3
Male	0.67	0.26	0.16	0.33	0.74	0.77	52.7
Female	0.56	0.33	0.30	0.53	0.82	0.82	48.3
$\bar{X}$ Total	0.63	0.28	0.22	0.42	0.76	0.80	50.9

r = Pearson-product correlation coefficient.

* Adjusted for missing data.

The correlations between maths achievement (PMAT2) and COGTOT, MS (Memory Space), READ and DICT all tend to increase from grade two to grade six. For visual memory (VM1 and VM2) just the opposite holds. In grade two visual memory seems equally related to mathematics achievement as language and general cognitive competence. In grade six, however, visual memory exhibits little relationship to achievement, while language and general cognitive competence show very large correlations with mathematics achievement. This result is reflected in the overall strong relationship between mathematics achievement, general cognitive ability and language competence. We suspect that in the early school years children rely on their well developed ability to memorize visual input (Bishop, 1979; Lean and Clements, 1980) while developing basic English skills. Over the next few years those children that reach some as of yet unidentified threshold of language competency excell in mathematics learning as well, while those remaining dependent on visual memory for processing mathematical input are overwhelmed with the vastly increasing symbolic load.

It would seem likely then that improving English language competence prior to grade four would have a significant effect on below average mathematics students, and perhaps the more competent students as well.

A slightly different pattern emerges when we consider differences in performance for males and females. Females exhibited poorer performance than males on PMAT2, COGTOT, DICT and MS, while surpassing the boys' achievement for VM1, VM2, READ and DELTA 32 (achievement gain). A pattern similar to that exhibited by changes across grades seems to exist for the general cognitive and memory measures. The READ and DICT results do not offer as clear an interpretation however. While the READ mean for females was slightly higher than for males, the boys outperformed the girls on mathematics achievement. The DICT results exhibit the expected relationship with mathematics achievement, however the correlation between DICT and PMAT2 is slightly higher for the girls than the boys.

This result supports the English language-competency threshold argument. Girls did not outperform the boys in mathematics achievement even though they exhibited marginally higher READ scores. Both language measures were more highly correlated with mathematics performance for females than for males. No clear patterns of relationships were apparent when comparing variations in performance across sites.

Multiple-Correlation Analysis: The results of the cognitive assessment were submitted to stepwise-multiple regression analysis using PMAT2 as the dependent variable. The goal of such an analysis is to determine which set of independent variables account for the greatest amount of variance in the dependent variable. The procedure involves selecting the independent variable with the greatest simple correlation and entering it into the regression equation. Next, all the remaining variables are tested to determine which one, in concert with the original, contributes most to the multiple correlation. If that variable meets certain tolerance level conditions it is subsequently included in the regression equation. The process continues whereby on each step the remaining variable that contributes most significantly to the multiple regression equation is included. The process ceases when no variable remains that can meet the tolerance condition. This type of analysis does not allow for systematic replacement of variables previously included in the predictor set when a new variable fails to contribute significantly to the regression solution.

A summary table is generated listing the set of variables which together are significantly correlated with the dependent variable (PMAT2). The variable accounting for the greatest amount of variance in the dependent variable (PMAT2) is listed first. Followed, in descending order, by the variables in the set.

Since grade and gender effects were significant, they were taken into account by entering grade level as an independent variable and computing a separate regression analysis for males and females. Tables 43 and 44 summarize the results of the stepwise regression analysis for males and females respectively. In both cases PMAT2 was regressed on GRADE, COGTOT, VM1, VM2, MS, READ and DICT. All variables loaded for each analysis.

Table 43

STEPWISE MULTIPLE REGRESSION SUMMARY TABLE (MALES)

Variable	R	R^2	R^2 Change	r
GRADE	0.81	0.66	0.66	0.81
COGTOT	0.86	0.74	0.08	0.67
DICT	0.88	0.77	0.03	0.77
READ	0.90	0.80	0.03	0.69*
VM1	0.90	0.80	0.00	0.27
MS	0.90	0.80	0.00	0.34
VM2	0.90	0.80	0.00	0.16

* Adjusted for missing data.
R = Multiple correlation coefficient.
R^2 = Measure of the percent of variance accounted for by independent variable(s)
r = Simple correlation coefficient.

As expected GRADE, COGTOT, DICT and READ contributed most to the regression equation, together accounting for more than 80% of the variance in PMAT2 scores (male). Of course grade level (number of years of schooling) is the most reliable predictor of maths achievement for boys in our sample, with cognitive and language competence providing an important contribution as well.

For females the situation is somewhat more complex.

Table 44

STEPWISE MULTIPLE REGRESSION SUMMARY TABLE (FEMALES)

Variable	R	R^2	R^2 Change	r
DICT	0.83	0.69	0.69	0.83
GRADE	0.87	0.76	0.07	0.82
MS	0.90	0.81	0.05	0.58
COGTOT	0.91	0.83	0.02	0.60
READ	0.92	0.84	0.01	0.75*
VM2	0.92	0.85	0.01	0.35
VM1	0.92	0.85	0.00	0.41

* Adjusted for missing data.

Again GRADE, COGTOT and DICT are together the most highly correlated with mathematics achievement, though MS (memory space) seems to play a more important role than for boys. Together these four variables account for approximately 83% of the variance in PMAT2 scores (female). In general, visual memory (VM1 and VM2) seems to contribute little to the overall regression equation which is consistent with the discussion in the previous section.

In summary, years of schooling, language ability and cognitive competence account for a considerable proportion of the variance associated with mathematics achievement. English language skill and short-term memory space seem slightly more important to success for girls as is cognitive competence for boys.

TEACHER ASSESSMENT

Teacher Survey: The results of the post implementation survey are presented below. The questions in table 45 and 46 were originally worded in mixed positive and negative tones. The results have been converted to positive statements only to assist the reader in interpreting the responses.

The scores range from +2 (strongly agree) to –2 (strongly disagree), with zero (0) representing uncertainty. The first set of questions deals with the IMP trial materials and the second set with more general methodology issues.

Table 45

TEACHER SURVEY QUESTIONS

	IMP Curriculum Related Questions	$\bar{X}$
1.	The language used in the Teacher's Notes made it easy to understand the lesson.	0.4
2.	The instructions to the class in the Teacher's Notes were easy to follow.	0.8
3.	Sufficient worked examples were given in the Teacher's Notes.	0.6
4.	The Teacher's Notes were useful when planning the lesson.	1.4
5.	The language use in the Student Booklet is suitable for **grade two** children.	0.8
6.	The language used in the Student Booklet is suitable for **grade four** children.	1.6
7.	The language used in the Student Booklet is suitable for **grade six** students.	1.0
8.	The Student Booklets make it easier for the children to learn.	2.0
9.	It was easy to pass out the Base-10 materials when they were needed.	1.2
10.	The Base-10 materials helped my students learn arithmetic.	1.8
11.	The Kina Cards helped my students learn to classify objects better.	0.8
12.	The Coin Cards were useful aids for teaching place-value and computation.	1.0
13.	The squared paper was useful for teaching place-value and computation.	1.6
14.	The measurement instruments were easy to use with my students.	1.0
	Grand $\bar{X}$	1.1

Table 46

TEACHER SURVEY QUESTIONS

	General Methodological Questions	$\bar{X}$
1.	It is easy for my pupils to work independently.	1.0
2.	Small group work helps children learn mathematics.	1.6
3.	Group work was easy for me to organize.	1.8
4.	The use of mathematical games helps children learn.	2.0
5.	More in-service training is required if I am to use the IMP materials well.	1.8
6.	The MACS Programme includes enough lessons on number operations.	¯0.4
7.	The content of the current MACS syllabus is appropriate for Papua New Guinea.	0.2
8.	If one teacher taught all the mathematics in my school, the children would learn more.	0.2

In general the five teachers expressed positive evaluations regarding the utility and effectiveness of the IMP trial curriculum materials ($\bar{X}$ = 1.1). They also indicated general agreement with the underlying philosophy and methodology which form the basis of the current MACS course and the IMP adaptation. The only negative response agreed to by the majority of respondents involved the quantity of number operation exercises currently included in the MACS course. This conclusion seems consistent with the opinions of the Department of Education personnel, a wide range of teachers in the field and many teacher trainers. Considerable disagreement remains, however, as to how to remedy the situation. The results summarized above are based on mean results across the five sites. It should be noted that the results varied somewhat from site to site. Table 47 below shows results by site.

Table 47

SUMMARY OF TEACHER SURVEY QUESTIONS BY SITE

Type of Question	MP	WSP	SHP	WHP	NCD	$\bar{X}$
Curriculum	1.6	0.2	1.1	1.1	1.6	1.1
Methodology	1.3	0.1	1.9	0.9	1.1	1.1
$\bar{X}$	1.4	0.2	1.5	1.0	1.4	1.1

The teacher from the West Sepik site seems unique among this group regarding his lack of enthusiasm for both the materials themselves and his committment to the underlying instructional methodology and philosophy. If true, it is not unreasonable to surmise that there is a relationship between the teacher's attitude and low student performance. It is difficult to determine which is the causal factor, however, under the current design.

Table 48 below gives a summary of teaching experience, age and sex by site, with provincial data included for comparison.

Table 48

SITE AND PROVINCIAL STUDENT POPULATIONS

Site	Years Experience $\bar{X}$	Student Age ($\bar{X}_A$)	Boys (%) At Site	Girls (%) At Site	% 7–12 Year-Olds In School*	Community School Enrollment*	Boys* (%)	Girls* (%)
MP	10.5	10.9	57	43	61.4	3 398	52	48
WSP	3.8	11.1	72	18	61.8	10 596	66	34
SHP	4.5	10.2	53	47	51.2	17 985	65	35
WHP	5.6	10.2	52	48	44.7	17 570	58	52
NCD	6.9	10.3	55	45	61.8	11 339	54	46
			56	44	57.7	277 301	60	40

$\bar{X}_A$ = School mean adjusted to take into account missing grade levels.
* Provincial 1979 data.

School commenced at 8:00 o'clock at two sites, 8:15 at another and 8:30 at the rest. In each case school was scheduled to be in session for seven hours (until 3:00, 3:15 and

3:30 respectively) with a half hour morning tea break and a one hour lunch break. The number of scheduled minutes per week of maths instruction was a consistent 210 minutes across all sites except the Manus school which reported 150 minutes of instruction per week. Observers indicated that during the IMP trialling period at least 150 minutes of maths instruction was actually carried out each five day week (at each grade level) and in some cases considerably more. The number of actual lessons implemented varied somewhat between sites, as did the number of days of instruction. Because of various emergencies (ie. death of the Southern Highlands Premier) and occasionally for no apparent reason (i.e. one site apparently got the holiday schedule confused and planned to close the school a week early), school was not held on one or more scheduled days at several sites. There were also several occasions where a personal emergency (death in the family) left the school shorthanded for extended periods as well. Table 49 shows lesson implementation data by site.

Table 49

LESSON IMPLEMENTATION BY SITE

Site	Grade Level	No. Lessons Implemented	Total Days Instruction (max 30)	PMAT2 $\bar{X}$
MP	4	23		54.6
	6	22		68.1
	$\bar{X}$	22.5	24	50.9*
WSP	2	20		25.7
	4	18		47.1
	6	24		56.7
	$\bar{X}$	20.7	24	42.3
SHP	2	29		36.1
	4	23		57.8
	6	31		75.1
	$\bar{X}$	27.7	26	56.4
WHP	2	26		31.1
	4	27		50.6
	6	26		56.8
	$\bar{X}$	26.3	27	48.1
NCD	2	19		25.5
	4	24		54.8
	6	22		66.4
	$\bar{X}$	21.7	25	48.9

*Adjusted for missing data.

It is interesting to note that the WSP and NCD sites completed somewhat fewer lessons on an average than the others. This could account for the low achievement scores at the WSP and the surprisingly undistinguished performance at NCD when compared to SHP. Variation in the actual number of lessons implemented could be attributed to differences in teaching style, motivation on the part of the teacher or students, the ability of the teacher to program and carry out the necessary pre-lesson preparation or the number of days school was in session. We feel the last two factors contributed most to differences in implementation rates.

Table 50 shows a profile of results for tests administered to each teacher. PMAT and Aiken were administered in April 1980. The Raven and teacher Survey were adminiistered in October 1980. Selected student results are also included.

Table 50

MEASURES OF TEACHER COMPETENCE

Site	Teacher Results					Site Results*			
	PMAT1 %	Aikens Maths Attitude −2 to +2	Roven ($\overline{X}$)	IMP Survey −2 to +2	Lessons $\overline{X}$	PMAT2 %	READ %	DICT %	COGT %
MP	87	1.4	87	1.4	22.5	50.9	72.3	68.1	68.1
WSP	79	1.6	83	0.2	20.7	42.3	63.6	67.7	47.4
SHP	84	1.5	86	1.5	27.7	56.4	72.1	68.4	71.9
WHP	93	1.4	86	1.0	26.3	48.1	61.1	57.1	59.5
NCD	83	1.5	85	1.4	21.7	48.9	74.2	67.6	60.4
$\overline{X}$	85.2	1.5	85.4	1.1	23.8	50.9	68.8	65.7	62.7

* Site results based on cognitive sample.
COGT = Total cognitive measure (CN + CL + LC + CI + DS).
Lessons ($\overline{X}$) = Mean number of lessons implemented per grade.

Of the five teacher variables, only the IMP survey results and the number of lessons taught seemed at all related to mean student achievement. Whether these were causal factors remains a question. However it seems safe to assume that a positive attitude on the part of the teacher towards the instructional materials in use has a positive effect on the number of lessons implemented and subsequent student achievement.

It seems appropriate to end this section with the comments by the teachers themselves. Each was asked to evaluate the effectiveness of the instructional materials, their experience implementing the lessons, and to comment on their interaction with the visiting observer.

"Concerning the instructional aids, I would say they were really handy for me during my six weeks of teaching IMP maths. The aids were really useful too. Without the materials I don't think the children would learn a lot". Another teacher commented, "I felt the materials were good but are a bit difficult, especially the grade two and six Teacher's Notes and student-activity books. Simple English should be used to suit the classes' abilities. For grade four, I think it was well planned and suitable. The activity-books were one of the advantages of the IMP. The children followed the lessons in their books while the teacher teaches from the Teacher's Notes".

"The IMP, to my understanding, provides more child centered lessons than teacher centered. This is really good, as children understand and learn best this way. The instructions in the Teacher's Notes are quite good, however some examples should be explained more thoroughly for difficult topics. I think IMP maths will upgrade and improve the Maths in Community Schools because children were kept very close and fully involved in the lessons".

"Teaching with IMP really helped the children work effectively and understand what they were to do in mathematics. The children were really busy right through the lesson.

I was greatly impressed with the games and methods used which I didn't know of before. I also had to learn some good ways of how to carry out a lesson without many materials. Using IMP made teaching interesting and easy!"

"I really enjoyed working with my IMP observer. She worked closely with me and helped me talk about ways of going about teaching IMP. I was very happy that I got help. Once I stopped and let her take the lesson so I could see how the game went. She helped me make the lessons interesting. She was a Professor of Psychology and could see how the children went about their work".

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APPENDICES

Appendix I	Proposed Schedule for Mathematics Curriculum Development – Grades One to Ten
Appendix II	Community School Mathematics – Recommended Grade One To Six Basic Objectives

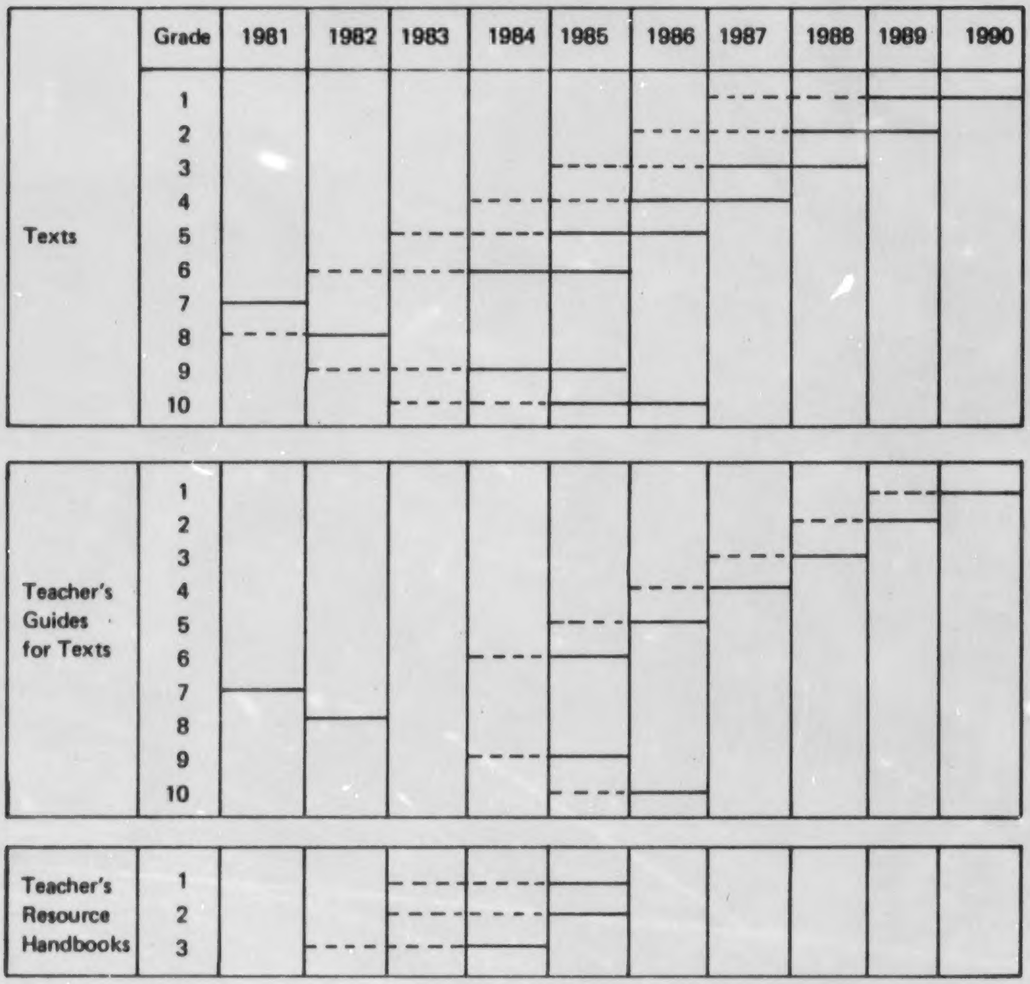
APPENDIX I

PROPOSED SCHEDULE FOR MATHEMATICS CURRICULUM DEVELOPMENT GRADES ONE TO TEN

By end of year	Activity
1981	– Review primary syllabus. – Review secondary Grades 9 and 10 syllabus. – Print, distribute and inservice Grade 7A and B texts. – Write, print and distribute Grade 7A and B Teacher's Guides.
1982	– Begin to design and write Grade 9 text. – Begin to design and write Grade 6 text. – Begin to design, write and trial Grade 3 Teacher's Resource Handbook. – Print, distribute and inservice Grade 8A and B texts. – Write, print and distribute Grade 8A and B Teacher's Guides.
1983	– Complete writing of Grade 9 text. – Complete writing of Grade 6 text. – Complete writing of Grade 3 Teacher's Resource Handbook. – Begin to design and write Grade 5 text. – Begin to design and write Grade 10 text. – Begin to design, write and trial Grades 1 and 2 Teacher's Resource Handbooks.
1984	– Begin to design and write the Grade 4 text. – Complete the writing of the Grade 5 text. – Begin the printing, distribution and the inservicing of the Grade 6 text. – Begin the printing, distribution and the inservicing of the Grade 9 text. – Complete the writing of the Grade 10 text. – Complete the writing of the Grades 1 and 2 Teacher's Resource Handbook. – Design, write and trial the Grade 6 Teacher's Guide. – Design, write and trial Grade 9 Teacher's Guide. – Revise, print, distribute and inservice Grade 3 Teacher's Resource Handbook.
1985	– Begin to design and write the Grade 3 text. – Complete the writing of the Grade 4 text. – Begin the printing, distribution and the inservicing of the Grade 5 text. – Complete the inservicing of the Grade 6 text. – Complete the inservicing of the Grade 9 text. – Begin the printing, distribution and the inservicing of the Grade 10 text. – Design, write and trial the Grade 5 Teacher's Guide. – Print, distribute and inservice the Grade 9 Teacher's Guide. – Design, write and trial the Grade 10 Teacher's Guide. – Print, distribute and inservice the Grades 1 and 2 Teacher's Resource Handbooks.

By end of year	Activity
1986	– Begin to design, write and trial the grade 2 text. – Complete the writing of the Grade 3 text. – Begin the printing, distribution and the inservicing of the Grade 4 text. – Complete the inservicing of the Grade 5 text. – Complete the inservicing of the Grade 10 text. – Design, write and trial the Grade 4 Teacher's Guide. – Print, distribute and inservice the Grade 5 Teacher's Guide. – Print, distribute and inservice the Grade 10 Teacher's Guide.
1987	– Begin to design, write and trial the Grade 1 text. – Complete the writing of the Grade 2 text. – Begin the printing, distribution and the inservicing of the Grade 3 text. – Complete the inservicing of the Grade 4 text. – Design, write and trial the Grade 3 Teacher's Guide. – Print, distribute and inservice the Grade 4 Teacher's Guide.
1988	– Complete the writing of the Grade 1 text. – Begin the printing, distribution and the inservicing of the Grade 2 text. – Complete the inservicing of the Grade 3 text. – Design, write and trial the Grade 2 Teacher's Guide. – Print, distribute and inservice the Grade 3 Teacher's Guide.
1989	– Begin the printing, distribution and inservicing of the Grade 1 text. – Complete the inservicing of the Grade 2 text. – Design, write and trial the Grade 1 Teacher's Guide. – Print, distribute and inservice the Grade 2 Teacher's Guide.
1990	– Complete the inservicing of the Grade 1 text. – Print, distribute and inservice the Grade 1 Teacher's Guide.

PROPOSED SCHEDULE FOR DEVELOPMENT, PRODUCTION AND IMPLEMENTATION OF TEXTBOOKS, TEACHER'S GUIDES AND RESOURCE HANDBOOKS



- - - - - Design, write and trial

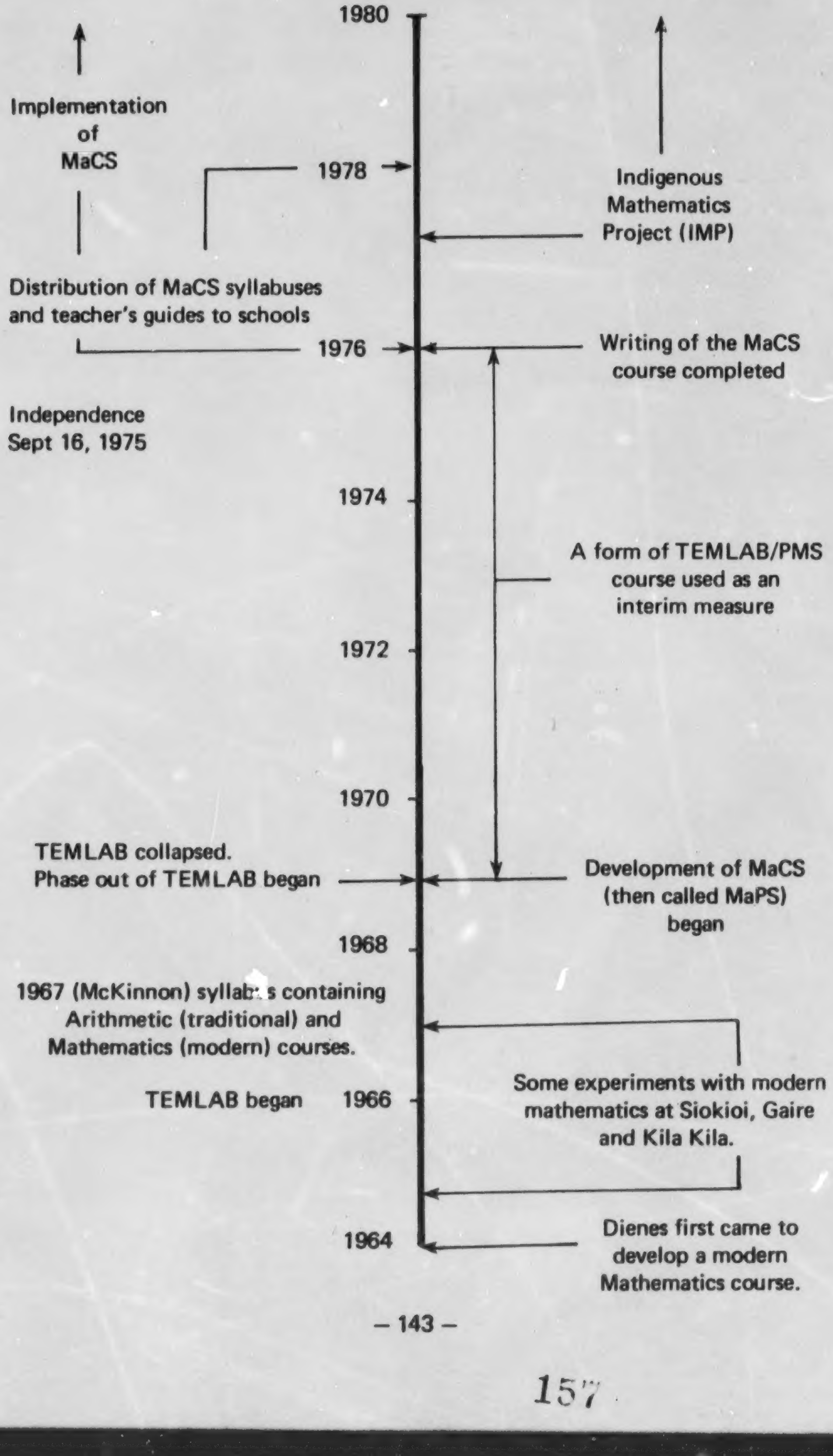
——— Revise, write, print distribute and inservice

Proposed funding

Texts and Teachers Guides:
Grades 7–10 PNG/UNESCO/New Zealand
Grades 4–6 World Bank
Grades 1–3 PNG/UNESCO

Teacher's Resource Handbooks:
Grade 1–3 PNG/UNICEF/UNESCO

TIMELINE SHOWING THE DEVELOPMENT OF THE PRIMARY MATHEMATICS CURRICULUM
1964 – 1980


1980
Implementation of MaCS
1978
Indigenous Mathematics Project (IMP)
Distribution of MaCS syllabuses and teacher's guides to schools
1976
Writing of the MaCS course completed
Independence Sept 16, 1975
1974
A form of TEMLAB/PMS course used as an interim measure
1972
1970
TEMLAB collapsed. Phase out of TEMLAB began
Development of MaCS (then called MaPS) began
1968
1967 (McKinnon) syllabus containing Arithmetic (traditional) and Mathematics (modern) courses.
TEMLAB began
1966
Some experiments with modern mathematics at Siokioi, Gaire and Kila Kila.
1964
Dienes first came to develop a modern Mathematics course.

APPENDIX II

COMMUNITY SCHOOL MATHEMATICS

RECOMMENDED GRADE ONE TO SIX BASIC OBJECTIVES

A review of the current Mathematics for Community School syllabus is planned in preparation for the development of upper grade textbooks (4–6) and expanded lower grade teacher handbooks (1–3). The attached scope and sequence suggestions are offered as a starting point for members of the Syllabus Advisory Committee (SAC). The following list of mathematics objectives have been compiled from various sources, most notably *Guide for Teaching Mathematics,* by Bethel, Callahan, et al, San Diego City Schools and *Mathmatters,* Souviney, Keyser and Sarver, Goodyear Publishing Co. The objectives listed should be considered as minimal, reflecting a basic level of achievement expected of all community school children. An 80% level of attainment for each objective seems reasonable for most children. Additional objectives addressing various enrichment topics might be deemed appropriate by the SAC or the Department. The exclusion of certain topics from the proposed basic objectives (ie. probability) should not suggest that these concepts are inappropriate. They may in fact be highly desirable. We attempt to provide objectives that address minimal standards expected of the vast majority of community school students.

The final selection of curriculum to be included in textbooks and handbooks should not be exclusively limited to those objectives determined to be minimal or basic by the SAC and the Department. Curriculum developers should endeavour to produce a curriculum that meets the needs of a wide range of abilities in order to assist the student in need of revision and extend those who learn quickly.

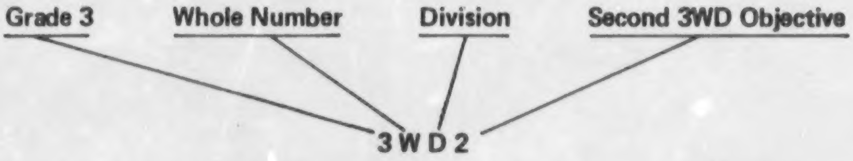
The objectives are divided into five content stands:

1. Number and Operations
2. Measurement
3. Geometry
4. Mathematical Language
5. Problem Solving Applications

The language objectives are included with the corresponding topics – number and operations, measurement and geometry. Though problem solving appears as a separate strand, the problem solving experiences should be carefully integrated into appropriate areas of number and operations, measurement and geometry.

Each objective included on the attached list are proceeded by a four character code. The first character refers to the intended grade level. The middle two letters indicate the content strand and subtopic. The final digit numbers the objectives sequentually within subtopic.

For example:



The codes for the content strands and subtopics are given in the table below:

OBJECTIVE CONTENT STRAND CODES

Strand	**Number and Operations** Whole (W) Fraction (F) Decimal (D)	**Measurement** (M)	**Geometry** (G)	**Mathematical Language** (L)	**Problem Solving Applications** (P)
Subtopics	Numeration (N) Addition (A) Subtraction (S) Multiplication (M) Division (D)	Linear (L) Weight (W) Money (K) Volume (V) Area (A) Angle (L)	Figures (F) Graphs (G)	Number and Operations (N) Measurement (M) Geometry (G)	Patterns (P) Classification (C) Applications (A)

(Example: 5DM3 = grade five, decimal multiplication, third DM for grade five).

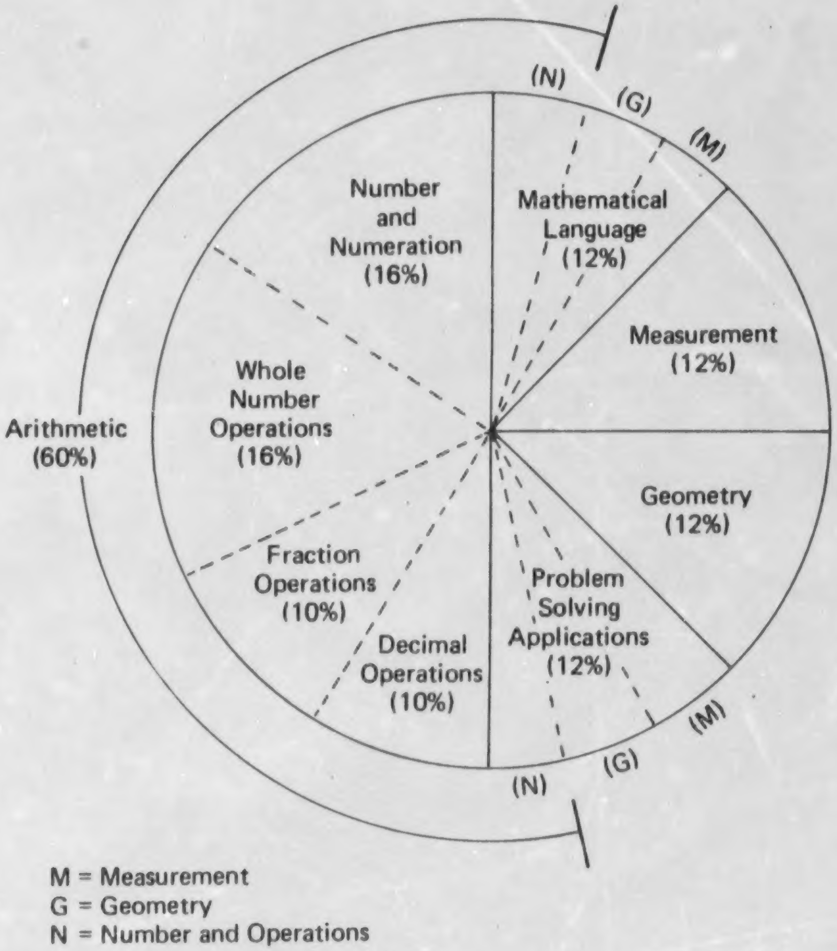
The following table provides a breakdown of objectives by grade level and content strand. By following across the rows the proposed scope of the subject matter can be determined for any grade level. By looking down the columns the sequence of objectives for each content strand can be traced, progressing through each subsequent grade.

SCOPE AND SEQUENCE CHART
BASIC MATHEMATICS OBJECTIVES FOR GRADES ONE TO SIX

Grade	Number and Operations (W), (F), (D)	Measurement (M)	Geometry (G)	Mathematical Language (L)	Problem Solving Applications (P)	n
1	1WN1, 1WN2, 1WN3, 1WN4, 1WA1, 1WS1, 1FN1	1MK1, 1ML1 1ML2	1GF1 1GG1	1LN1, 1LM1 1LG1	1PP1, 1PC1 1PC2, 1PC3	19
2	2WN1, 2WN2, 2WN3, 2WN4 2WN5, 2WN6, 2WN7, 2WA1 2WA2, 2WA3, 2WS1, 2WS2 2WS3, 2FN1	2MK1, 2ML1 2ML2	2GF1 2GG1	2LN1, 2LM1 2LG1	2PP1, 2PC1	24
3	3WN1, 3WN2, 3WN3, 3WN4 2WN5, 3WN6, 3WN7, 3WA1 3WA2, 3WA3, 3WA4, 3WS1 3WS2, 3WS3, 3FN1	3MK1, 3ML1 3MW1	3GF1 3GG1	3LN1, 3LM1 3LG1	3PP1, 3PC1 3PA1	26
4.	4WN1, 4WN2, 4WA1, 4WA2 4WA3, 4WA4, 4WS1, 4WS2 4WS3, 4WS4, 4WM1, 4WM2 4WM3, 4WM4, 4WM5, 4WD1 4WD2, 4WD3, 4WD4, 4FN1	4ML1, 4MK1	4GF1 4GF2	4LN1, 4LM1 4LG1	4PA1	29
5	5WN1, 5WA1, 5WS1, 5WM1 5WM2, 5WM3, 5WM4, 5WM5 5WM6, 5WD1, 5WD2, 5WD3 5WD4, 5WD5, 5FN1, 5FN2 5FA1, 5FS1, 5DN1	5MK1, 5MK2 5ML1, 5MA1 5MV1, 5MV2	5GF1 5GF2 5GG1	5LN1, 5LM1 5LG1	5PA1	33
6	6WN1, 6WA1, 6WS1, 6WM1 6WM2, 6WM3, 6WM4, 6WD1 6WD2, 6WD3, 6FN1, 6FN2 6FA1, 6FS1, 6DN1, 6DN2 6DN3	6ML1, 6MA1 6MV1, 6MV2 6MW1	6GF1 6GF2 6GG1 6GG2	6LN1, 6LM1 6LG1	6PA1, 6PA2 6PA3	32
Total	92 (56%)	22 (13%)	17 (10%)	18 (11%)	14 (9%)	163 (100%)

The emphasis alloted to each of the content strands should roughly follow the percent-of-total figures in the Scope and Sequence chart. Though the amount of time alloted to each topic will vary somewhat from grade to grade, it is recommended that the proportions approximate those presented in the circle-graph below.

CONTENT STRAND EMPHASIS
PERCENT OF TOTAL (%)



BASIC OBJECTIVES – GRADE ONE

1WN1 1. The student will be able to match objects (0–10) in one-to-one correspondence.

1WN2 2. The student will be able to match objects by one-to-one correspondence to identify which of two sets (0–10) has more, fewer, or the same number of members.

1WN3 3. The student will be able to count objects from 0 to 10 and sequence sets from 0 to 10, matching with the correct numeral.

1WN4 4. The student will be able to count sets of from 0 to 10 members and write the correct numeral symbol and words.

1WA1 5. The student will be able to demonstrate the concept of addition by joining two sets whose sum is six or less.

1WS1 6. The student will be able to demonstrate the concept of subtraction by a set of six or less.

1FN1 7. The student will be able to identify one-half of a region or object.

1LN1 8. The student will demonstrate an understanding of the meaning and usage of the following number and operation terms:

fewer
more
most
number
one, two, . . . ten
same
set

1MK1 9. The student will be able to match a 5-toea coin with five 1-toea coins.

1ML1 10. The student will be able to compare similar objects to determine which is longer; larger; shorter; smaller; or taller.

1ML2 11. The student will be able to order three similar objects according to their length.

1LM1 12. The student will demonstrate an understanding of the meaning and usage of the following measurement terms:

five toea
larger
longer
longest
one toea
shorter
shortest
size
smaller
taller
tallest

1GF1 13. The student will be able to identify circles, triangles, squares and rectangles.

1GG1 14. The student will participate in a graphing project.

1LG1 15. The student will demonstrate an understanding of the meaning and usage of the following geometry terms:

above
after
alike
before
below
beside
between
bottom
circle
different
down
left
over
rectangle
right
same
shape
square
top
triangle
under
up

1PP1 16. The student will recognize a simple pattern and identify the member which comes next. For example:

□ ○ □ ○ ?

1PC1 17. The student will demonstrate classification skills by grouping objects in terms of a common attribute.

1PC2 18. The student will be able to locate objects using positional words: "bottom", "above", "below", "up", "between", "down", "on", "under" "beside", "over", "after", "right", "left".

1PC3 19. The student will be able to describe objects by telling how they are **alike** and how they are **different**.

BASIC OBJECTIVES – GRADE TWO

2WN1 1. The student will be able to match objects (0–10) in a one-to-one correspondence (revision).

2WN2 2. The student will be able to count sets of objects to 10, match the correct numeral to the set, and write and sequence numerals from 0 to 10.

2WN3 3. The student will be able to identify which of two sets (0–99) has more, fewer, or the same number of members.

2WN4 4. The student will demonstrate understanding of regrouping ones and tens using base-10 materials and coins.

2WN5 5. The student will be able to represent a two digit number using base-10 materials and coins.

2WN6 6. The student will be able to count, read, write and sequence numerals from 0 to 99.

2WN7 7. The student will be able to write a standard numeral for a given number of 10's and 1's and identify the number of 10's and 1's for any number from 0 to 99.

2WA1 8. The student will be able to concretely demonstrate and record addition with a set of base-10 materials, then coins, for sums of 10 or less.

2WS1 9. The student will be able to concretely demonstrate and record subtractions with a set of base-10 materials, then coins, with minuends (top number) 10 or less.

2WA2 10. The student will be able to concretely add any two whole numbers whose sum is five or less and record the results in squared paper place-value tables.

2WS2 11. The student will be able to concretely subtract any two whole numbers with minuends 5 or less and record the results in place-value tables.

2WA3 12. The student will be able to concretely add any two whole numbers whose sum is 10, 12, then 18 or less and record the results in place-value tables. (addition facts)

2WS3 13. The student will be able to concretely subtract any two whole numbers with minuends 10, 12, then 18 or less and record the results in place-value tables. (subtract facts)

2FN1 14. The student will be able to identify halves and fourths of a region or object.

2LN1 15. The student will demonstrate an understanding of the meaning and usage of the following number and operation terms:

add
difference
different
equal
fewer
greater-than
less-than
match
more
number sentence
one-half
one-fourth
tens
+, –, =
1, 2, . . . 10

2MK1 16. The student will form sets of 1-toea, 2-toea, 5-toea and 20-toea coins equivalent to 25 toea.

2ML1 17. The student will be able to demonstrate understanding of the terms "longer", "longest", "shortest", "taller", "tallest", "largest", "smallest", and "the same length or size" by identifying objects or pictures of objects that fit the description.

2ML2 18. The student will have experience measuring length using nonstandard or traditional units.

2ML1 19. The student will demonstrate an understanding of the meaning and usage of the following measurement terms:

graph
hour
kina
larger
longer
longest
patterns
shorter
shortest
size
smaller
smallest
taller
tallest
toea
unit
week

2GF1 20. The student will be able to identify circles, triangles, rectangles and squares and identify curves as open or closed.

2GG1 21. The student will contribute pertinent information about themselves to a class graphing project, participate in group decisions as to how to organize and record data, and participate in drawing conclusions from the graphed information that will include "more-than", "less-than", and/or "the same".

2LG1 22. The student will demonstrate an understanding of the meaning and usage of the following terms:

circle
classify
closed-curve
open-curve
rectangle
shape
square
triangle

2PP1 23. The student will be able to recognize and continue a simple pattern of shapes. For example:

□ ◇ ○ □ ◇ ? ? ?

2PC1 24. The student will be able to demonstrate classification skills by grouping objects and pictures in terms of a common attribute.

BASIC OBJECTIVES – GRADE THREE

3WN1 1. The student will be able to name the ordinal numbers first to tenth by pointing to objects in a line.

3WN2 2. The student will be able to write any two digit number represented by base-10 materials and coins and vice versa.

3WN3 3. The student will be able to count, read, write, sequence and identity the place-value of any numeral from 0 through 99.

3WN4 4. The student will be able to count by 2's and 5's.

3WN5 5. The student will be able to write any three digit number represented by base-10 materials and coins and vice versa.

3WN6 6. The student will demonstrate understanding of regrouping ones, tens and hundreds using base-10 materials and coins.

3WN7 7. The student will be able to count, write and sequence numerals from 0 to 999.

3WA1 8. The student will be able to add any two one-digit whole numbers whose sum is 18 or less. (addition facts – revision)

3WS1 9. The student will be able to subtract any whole numbers with minuends 18 or less. (subtraction facts – revision)

3WA2 10. The student will be able to concretely add three or more addends whose sum is 18 or less and record the results in squared-paper place-value tables.

3WA3 11. The student will be able to concretely add any two whole numbers less than 100 without regrouping and record the results in place-value tables.

3WS2 12. The student will be able to concretely subtract any two whole numbers less than 100 without regrouping and record the results in place-value tables.

3WA4 13. The student will be able to concretely add two whole numbers whose sum is less than 100, regrouping as necessary and record the results in place-value tables.

3WS3 14. The student will be able to concretely subtract two whole numbers less than 100, regrouping as necessary and record the results in place-value tables.

3FN1 15. The student will be able to identify halves and fourths of a region or set.

3LN1 16. The student will demonstrate an understanding of the meaning and usage of the following number and operation terms:

add
difference
equal
first
less-than (<)
more-than
number sentence
numeral
one-third ($\frac{1}{3}$)
one's-place
order
place-value
set
subtract
sum
ten's-place

greater-than (>)
hundred's place
one-half ($\frac{1}{2}$)
one fourth ($\frac{1}{4}$)
regroup
same
+, −, =
1, 2, . . . 999

3MK1 17. The student will form sets of 1-toea, 2-toea, 5-toea, 10-toea, 20-toea coins equivalent to 50 toea.

3ML1 18. The student will be able to measure length using traditional units and metres.

3MW1 19. The student will have experience comparing the weights of objects using a balance scale.

3LM1 20. The student will demonstrate an understanding of the meaning and usage of the following measurement terms:

centimetre
coins
graph
half-hour
hour
kina (K)
longer
longest
patterns
shorter
shortest
toea (t)
unit
weight
week

3GF1 21. The student will be able to identify circles, triangles, rectangles, squares and their features (ie. corners, sides, etc.).

3GG1 22. The students will contribute pertinent information about themselves to a class graphing project, participate in group decisions as to how to organize and record data, and participate in drawing conclusions from the graphed information that will include "more-than", "less-than", and/or "the same". (revision)

3LG1 23. The student will demonstrate an understanding of the meaning and usage of the following terms:

and (conjunction)
circle
closed-curve
corner
open-curve
or (inclusive disjunctive)
rectangle
side
square
triangle

3PP1 24. The student will be able to recognize and continue a simple number pattern. For example: 5, 10, 15, __?__, __?__, __?__.

3PP1 25. The student will be able to demonstrate classification skills by grouping objects and pictures according to two attributes ("and" – conjunction; "or" – inclusive disjunction).

3PA1 26. The student will be able to solve simple picture story problems involving counting, addition, subtraction, length, time or money.

BASIC OBJECTIVES – GRADE FOUR

4WN1 1. The student will be able to concretely represent, using base-10 materials and coins, count, read, write, sequence and identify the place-value of any numeral from 0 to 999. (revision)

4WN2 2. The student will be able to concretely represent, using base-10 materials and coins, count, read, write, sequence and identify the place-value of any numeral from 0 to 9999.

4WA1 3. The student will be able to add any two or three one-digit whole numbers whose sum is 18 or less. (addition facts – revision)

4WS1 4. The student will be able to subtract any two whole numbers with minuends 18 or less. (subtraction facts – revision)

4WA2 5. The student will be able to add two or three whole numbers less than 100 in place-value tables, regrouping as necessary. (revision)

4WS2 6. The student will be able to subtract two whole numbers less than 100, in place-value tables, regrouping as necessary. (revision)

4WA3 7. The student will be able to concretely add two whole numbers less than 1,000 without regouping and record the results in place-value tables.

4WS3 8. The student will be able to concretely subtract two whole numbers less than 1,000 without regrouping and record the results in place-value tables.

4WA4 9. The student will be able to concretely add two whole numbers less than 1,000, regrouping as necessary and record the results in place-value tables.

4WS4 10. The student will be able to concretely subtract two whole numbers less than 1,000, regrouping as necessary and recording the results in place-value tables.

4WM1 11. The student will be able to demonstrate the repeated addition concept of multiplication using objects.

4WD1 12. The student will be able to demonstrate the concept of division by separating a set into equivalent subsets.

4WM2 13. The student will be able to demonstrate the matrix concept of multiplication using base-10 materials.

4WD2 14. The student will be able to demonstrate the matrix concept of division (inverse of multiplication) using base-10 materials.

4WM3 15. The student will be able to concretely multiply two numbers with one factor less than six and the other less than 10 and record the results in place-value tables.

4WM4 16. The student will be able to concretely multiply two numbers less than 10 record the results in place-value tables (multiplication facts).

4WM5 17. The student will be able to complete the 10 x 10 multiplication table with 80% accuracy.

4WD3 18. The student will be able to concretely divide a number using basic facts with the divisor less than 6 and the dividend less than 20 and record the results in place-value tables.

4WD4 19. The student will be able to concretely divide using basic facts to 81 ÷ 9 with no remainder and record the results in place-value tables.

4FN1 20. The student will be able to identify halves, thirds, fourths, fifths and sixths of a region or set and write the fraction.

4LN1 21. The student will demonstrate an understanding of the meaning and usage of the following number and operation terms:

digit
divide
even
fraction
fractional part
greater-than (>)
half, third, fourth . . . $(\frac{1}{2}, \frac{1}{3}, \frac{1}{4} \ldots)$
hundred
less-than (<)
multiply
odd
one's place
product
regroup
set
ten's place
thousand
x, ÷

4ML1 22. The student will be able to measure length to the nearest centimetre and tell time to within five minutes.

4MK1 23. The student will be able to count a collection of coins and notes (K5 or less).

4LM1 24. The student will demonstrate an understanding of the meaning and usage of the following measurement terms:

centimetre (cm)
coins
degrees Celcius ($^{\circ}$C)
graph
hours
metre (m)
minutes
same-measure
temperature
weight

4GF1 25. The student will be able to identify geometric shapes (circle, triangle, rectangle, square) and their features (corner, side, perimeter, diameter).

4GF2 26. The student will be able to identify geometric solids (box, sphere).

4GG1 27. The student will participate in a small-group graphing activity which will include gathering statistical information, organising the information in a graph, and interpreting the graph.

4LG1 28. The student will demonstrate an understanding of the meaning and usage of the following geometry terms:

circle
corner
diameter
edge
face
geometric figure
line
perimeter
rectangle
radius
sphere
square
triangle

4PA1 29. The student will be able to solve simple story problems involving addition and subtraction of whole numbers and money.

BASIC OBJECTIVES – GRADE FIVE

5WN1	1.	The student will be able to count, read, write, sequence and identify the place-value of any numeral 0 to 999,999.
5WA1	2.	The student will be able to add two whole numbers less than 10,000, regrouping as necessary.
5WS1	3.	The student will be able to subtract two whole numbers less than 10,000 regrouping as necessary.
5WM1	4.	The student will be able to multiply two numbers less than 10. (multiplication facts revision)
5WD1	5.	The student will be able to divide a number using basic facts with no remainder. (revision)
5WM2	6.	The student will be able to concretely multiply a number less than 100 by a number less than 10, regrouping as necessary and record the results in place-value tables.
5WM3	7.	The student will be able to multiply a number less than 1,000 by a number less than 10, regrouping as necessary using place-value tables.
5WD2	8.	The student will be able to concretely divide a number using basic facts, identify the remainder and record the results using place-value tables. For example: $4\overset{8\ R\,3}{\overline{)35}}$
5WD3	9.	The student will be able to concretely divide a number less than 100 by a number less than 10, first without, then with remainder (64 ÷ 2 = 32; 87 ÷ 4 = 21 R3) and record the results in place-value tables.
5WM4	10.	The student will be able to multiply a number by a multiple of 10 or 100 using place-value tables.
5WD4	11.	The student will be able to divide a number less than 1,000 by a number less than 10 requiring simple estimation – first without, then with a remainder (697 ÷ 3 = 232 R1) – using place-value tables.
5WM5	12.	The student will be able to concretely multiply any two numbers less than 100 regrouping as necessary and record the results in place-value tables.
5WM6	13.	The student will be able to multiply any number less than 1000 by any number less than 100, regrouping as necessary and record the results in place-value tables.
5WD5	14.	The student will be able to concretely divide any number less than 1000 by any number less than 100, first without, then with remainders and record the results in place-value tables.
5FN1	15.	The student will be able to identify halves, thirds, fourths, fifths, sixths, eighths, and tenths of a region or set and write the fraction. (revision)
5FN2	16.	The student will be able to concretely represent fractions using a fraction kit and write a fraction equivalent to a given fraction (halves, thirds, fourths, fifths, sixths, and tenths).

5FA1 17. The student will be able to concretely add fractions with like denominators and record the results.

5FS1 18. The student will be able to concretely subtract fractions with like denominators and record the results.

5DN1 19. The student will be able to concretely represent, using coins, say and read decimals in tenths and hundredths written in place-value tables.

5LN1 20. The student will demonstrate an understanding of the meaning and usage of the following number and operation terms:

common multiple
digit
even
fractional part
greater than (>)
half, third, fourth . . . ($\frac{1}{2}, \frac{1}{3}, \frac{1}{4}$ . . .)
hundredth's-place (0.01)
less than (<)
million
odd
tenth's place (0.1)
thousand

5MK1 21. The student will be able to count a collection of coins and notes (K10 or less).

5MK2 22. The student will be able to count change for items less than K1.00

5ML1 23. The student will have experience measuring the weight (mass) of the objects in the environment using non-standard and kilogram units.

5MA1 24. The student will be able to measure area by counting centimetre square units.

5MV1 25. The student will have experiences finding the volume of rectangular boxes using various non-standard and metric units (ie. seeds, shells, blocks, cubic centimetres, etc.).

5MV2 26. The student will have experience determining the capacity of containers from the environment in litres.

5LM1 27. The student will demonstrate an understanding of the meaning and usage of the following measurement terms:

area
area of square
capacity
centimetre (cm)
degrees Celcius (°C)
edge
gram
hours
kilogram (kg)
litre (l)
mass
metre (m)
millimetre (mm)
minute
perimeter
same-measure
second
squared centimetre (cm^2)
square metre (m^2)
square unit
temperature
volume of a box
weight

5GF1 28. The student will be able to identify simple geometric shapes (circles, triangles, quadralaterals).

5GF2 29. The student will be able to identify simple geometric solids (box, sphere and cylinder) and their properties. (revision)

5GG1 30. The student will be able to plot one or more points on a coordinate-plane, when given number pairs.

5GG2 31. The student will be able to construct and interpret a pictograph or a bar graph.

5LG1 32. The student will demonstrate an understanding of the meaning and usage of the following geometry terms:

- circle
- cylinder
- diameter
- geometric figure
- rectangle
- sphere
- square
- triangle

5PA1 33. The student will be able to solve problems involving one or two of the basic operations (+, –, x, ÷) using whole numbers and decimals (money).

BASIC OBJECTIVES – GRADE SIX

6WN1 1. The student will know the common properties of numbers and be able to read, write, sequence and identify the place-value of any numeral to the hundred million's place.

6WA1 2. The student will be able to add three whole numbers less than 10,000 regrouping as necessary with and without place-value tables. (revision)

6WS1 3. The student will be able to subtract any two numbers less than 10,000, regrouping as necessary with and without place-value tables. (revision)

6WM1 4. The student will be able to multiply any two numbers less than 10. (multiplication facts – revision)

6WM2 5. The student will be able to multiply any number less than 1,000 by any number less than 10, regrouping as necessary with and without place-value tables. (revision)

6WD1 6. The student will be able to divide a number less than 100 by a number less than 10 with and without a remainder, using place-value tables and without. (revision)

6WM3 7. The student will be able to multiply any two whole numbers which are less than 100, regrouping as necessary with place-value tables and without. (revision)

6WM4 8. The student will be able to multiply any number less than 1,000 by any number less than 100, renaming as necessary, with and without place-value tables. (revision)

6WD2 9. The student will be able to divide any number less than 1,000 by any number less than 10, with and without a remainder, using place-value tables and without. (revision)

6WD3 10. The student will be able to divide any number less than 1,000 by any number less than 100 with and without a remainder, using place-value tables and without. (revision)

6FN1 11. The student will be able to write an equivalent fraction for a given fraction (halves, fourths, thirds).

6FN2 12. The student will be able to concretely represent and write fractions in simplest terms (halves, fourths, thirds and tenths).

6FA1 13. The student will be able to concretely add fractions with like denominators, record the results. (revision)

6FS1 14. The student will be able to concretely subtract fractions with like denominators, record the results. (revision)

6DN1 15. The student will be able to concretely represent, using base-10 materials and coins, say, read and write decimals in tenths and hundredths using place-value tables.

6DN2 16. The student will be able to rename fractions in tenths and hundredths as decimal fractions and vice versa.

6DN3 17. The student will be able to change a decimal expressed in tenths and hundredths to a percentage.

6LN1 18. The student will demonstrate an understanding of the meaning and usage of the following number and operation terms:

digit
even
greater-than (>)
hundredth's place (0.01)
less than (<)
million's-place
odd
percentage
tenth's place (0.1)

6ML1 19. The student will be able to measure to the nearest centimetre and millimetre.

6MA1 20. The student will be able to determine the area of a rectangle in centimetre square units.

6MV1 21. The student will have experiences finding the volume of rectangular boxes from the environment using cubit units (wooden cubes, cubic centimetres, etc.).

6MV2 22. The student will have experiences determining the capacity of containers from the environment in litres and millilitres.

6MW1 23. The student will have experiences determining the weight (mass) of objects from the environment in kilograms and grams.

6LM1 24. The student will demonstrate an understanding of the meaning and usage of the following measurement terms:

area
area of a square
capacity
centimetres (cm)
degrees Celcius (°C)
edge
gram (g)
hours
kilograms (kg)
mass
metre (m)
millimetre (mm)
minute
perimeter
second
square centimetre (cm^2)
square metre (m^2)
square unit
temperature
volume of a box
weight

6GF1 25. The student will be able to identify geometric shapes (circles, triangles, quadrilaterals) and their parts (angle, side, diagonal, radius, perimeter, diameter and line-of-symmetry).

6GF2 26. The student will be able to identify simple geometric solids (cubical and rectangular boxes, spheres and cylinders) and their properties (face, edge, corner, perimeter, diameter). (revision)

6GG1 27. The student will be able to graph ordered-pairs on the cordinate-plane.

6GG2 28. The student will be able to construct and interpret a pictograph and bar graph.

6LG1 29. The student will demonstrate an understanding of the meaning and usage of the following geometry terms:

angle
bar graph
circle
coordinate-plane
cylinder
diagonal
diameter
geometric figure
line-of-symmetry
ordered-pair
pictograph
plane
quadrilateral
radius
rectangle
region
side
sphere
symmetry
triangle

6PA1	30.	The student will be able to solve verbal problems involving one or more of the basic operations and percent.
6PA2	31.	The student will be able to use data to determine averages (mean).
6PA3	32.	The student will participate in a probability activity and be able to determine the probability of the experiment.

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